SILICA WASTE UTILIZATION

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KEYWORDS

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PROJECT BACKGROUND AND STATUS

The Geo-Heat Center has been investigating the use of waste silica from the Cerro Prieto geothermal field for several years (Lund et al., 1995). The Cerro Prieto geothermal field has an installed capacity of 620 MW, and in the process generated 6,800 tonnes/hr of brine consisting of 5 to 6 tonnes/hr of silica. Since the geothermal fields of the area extend into the Imperial Valley of California where waste silica is produced from an additional 420 MW of geothermal power generation, it is hoped that this research would also be applicable to the U.S. side of the border.

The conclusions from the original research (Lund et al., 1994, 1995) were that (1) the silica-lime mixtures had low strength and weather resistance, but high insulating properties, (2) additions of fibers to the silica-lime mixtures increased the strength, (3) silica-cement mixtures had high strength and weather resistance, but lower insulating values, (4) silica-asphalt mixtures were not suitable for road surfacing, and (5) silica-cement mixtures appeared to have application as road surfacing material.

The shortcoming of the original research was that the silica was obtained from evaporite deposits at a silencer. Since this source was not typical of the majority of silica waste at Cerro Prieto, additional material was obtained from their disposal ponds that cover 12 km^2 of area.

This project was started in July 1995 and should be completed by October 1996. The project is about 50% completed.

PROJECT OBJECTIVES

This project is investigating the utilization of waste silica from the evaporation ponds at Cerro Prieto geothermal field in Mexico. The main objective is to mix various combinations of hydrated lime, portland cement, and plastic fibers with the waste silica to determine their suitability for use as insulating bricks in low-cost housing.

Technical Objectives

- Produce mixes by combining the silica with various additives to determine their suitability for use as insulating bricks in low cost housing.
- Field test a wall of bricks constructed from the most suitable combination of silica and additive.
- Evaluate the design of a pilot fruit dehydrator constructed at the Los Azufres geothermal field in central Mexico.

Expected Outcomes

- Utilization of waste silica produced as a result of geothermal power generation.
- Demonstrate the advantages of starting a brick and tile manufacturing process utilizating the waste silica, based on (1) low cost and (2) high insulating value (low thermal conductivity).
- Demonstrate the advantages of using geothermal energy in fruit dehydration

APPROACH

Two silica samples were obtained from different locations in the Cerro Prieto disposal pond, and will be referred to as Sample 2 and 3, respectively, in this summary.

The silica is combined with the various additives: hydrated lime, cement, hydrated lime with fibers, and cement and hydrated lime in different proportions. The mixtures are formed into 7.60 cm by 5.10 cm by 15.2 cm brick molds for flexural testing and 5.10 cm square molds for compression testing. The samples are then allowed to cure for 7, 14 or 28 days by a moist or heat curing method. The moist curing method is in a water bath held at a temperature of 25°C. The heating method places a sample within a sealed container held at 60°C. Following the allocated curing time, the bricks are tested for flexural strength by a three point loading method. and the cubes are tested in compression. The samples are then dried and subjected to a 10-day weathering cycle. A weathering cycle consists of the sample being subjected to simulated rain by spraying until the sample is submerged in water and held at this state for 12 hours; then, it is placed in a oven at 60°C for an additional 12 hours.

RESEARCH RESULTS

Silica

The new silica samples have higher moisture contents, more visible individual crystals, and are coarser grained than the previous material obtained from the silencer. The higher moisture content was due to the material being sampled under water in the disposal ponds. The specific gravity of the new samples are slightly lower at 2.27 (2) and 2.18 (3) versus 2.29 for the original work. The composition is almost entirely silica with no significant trace minerals. As a result, the bricks and cubes have specific gravities that are 15 to 40 percent higher than in previous work.

Hydrated Lime

The silica-hydrated lime mixtures again produced the lowest specific gravities, thus indicating that they will have the best insulating values (low thermal conductivity).

The results of the 7-day flexural strength testing are shown in Figure 1. The result of the previous testing (Lund et al., 1995) are labelled at "1" and the two current samples as "2" and "3". In the phase II testing it became apparent that there was something wrong with our testing procedure since the 14-day and 28-day strengths were less than the 7-day strength. This is contrary to classical testing of lime mixtures (Transportation Research Board Committee on Lime and Lime-Fly Ash Stabilization, 1987), where strengths increase with the time of curing. This anomaly in our test results was not so evident in the original testing, but is readily apparent with the Phase II mix designs in Figure 2.

Upon a detailed investigation, it appears that our samples were drying out in the oven which prevented adequate curing and produced minute thermal cracks in the bricks. The longer the curing time the more thermal cracks that were produced. The samples then failed along these thermal cracks.

Because of the strength of lime-stabilization is both time and temperature dependent, the mixture design process is complicated. For curing lime stabilized samples, temperatures above about 23°C (considered ambient temperature) are used to accelerate formation of pozzolanic reactive products and thus reduce the need for long term curing and to estimate long term strengths. However, if elevated curing temperatures are too high, the pozzolanic compounds formed during laboratory curing could differ substantially from those that would develop in the field. Curing at 60°C is generally the highest temperature used and produces long term results in a short period of time (Townsend and Donaghe, 1976). Curing mixtures at 40°C, 50°C and 60°C is equivalent to producing 28-days strength in 69, 32 and 12 hours respectively (Biswas, 1972). Recent research indicates that elevated curing temperatures in excess of 50°C should be avoided, with 40°C recommended without introducing pozzolanic reactive products that significantly differ from those expected during the field curing (Transportation Research Board Committee on Lime and Lime-Fly Ash Stabilization, 1987).

Based on the above finding, two changes in our procedure were introduced 1) heat curing at 40°C instead of 60°C, and 2) curing in a moisture-proof plastic bag instead of tape-sealed pans. The results of this revised procedure can be seen in Figure 1. Mix design 2P was cured at 40°C in a tape sealed pan, and mix design 2Q was cured at 40°C in a moisture-proof plastic bag. The 7-day sample of 2P lost 40 grams of water while the 2Q sample lost 6 grams of water during curing as is evident in Figure 2. The lower curing temperature produced higher strengths and the moisture-proof bag curing produced higher strengths at 14- and 28-days. The results from mix 2Q are probably a better indication of what can be obtained in the field, providing that moist curing is achieved. The sample "3" mixes were all cured at 40°C.

Portland Cement

Cement stabilization produced higher strengths as compared to those obtained from the original testing (Figure 3). The strengths are approximately twice that of the corresponding silica-lime samples. The flexural strengths appear to be more dependent upon the amount of mixing water used, as the lower water/cement ratios produce higher strength. Additional testing was performed concerning the water/cement ratio. Mix 2N and 2O were mixed with the same proportions; but, 2N had 20% more water added which produced a higher water/cement ratio for 2N. From Figure 3, it is evident the strength is lower for 2N than 2O. Specific gravities of the new samples were as much as 40 percent higher than in the original testing.

Portland Cement and Hydrated Lime

The results from the combined cement and lime stabilization produced strengths between those obtained from just lime or cement alone (Figure 4). The silica:cement:lime ratios of 2:1:1 by weight should be compared with either the lime cement ratio of 1:1, and the 4:1:1 compared with 2:1. There appears to be no advantage to using this mixture unless the cost of lime is considerably less than cement, and strengths higher than those obtained from just lime stabilization are desired.

Hydrated Lime and Plastic Fibers

Approximately eight grams of plastic fibers, varying between 1.4 and 2.7 percent of dry weight of sample, were used to provide additional flexural strength to the lime stabilized samples. This produced significantly higher strengths than those samples cured at 60°C and only sightly higher strengths when compared with those cured at 40°C. However, the fiber samples were all cured at 60°C, thus additional testing will be performed at 40°C.

Weathering

The new samples performed well during the wet-dry weathering test. The "2" samples ranged from 2.3 to 47.0 percent loss, compared to the original samples which ranged from 3.7 to 100 percent loss. Most of the original silica-lime samples failed (average 91.0 percent lost); while, the "2" samples averaged a 15.9 percent loss. With the advent of a lower curing temperature for the silica-lime "3" samples, thus minimizing thermal cracking, it is estimated that they will perform better than sample "2."

FUTURE PLANS

- Further testing of the silica samples.
- The thermal conductivity will be tested by USGS in Menlo Park, California.
- Field test of a wall of bricks constructed from the most suitable combination of silica and additives.
- Chemical analysis of the silica by Brookhaven National Lab and Tasman Pulp and Paper in Kawerau, New Zealand.
- Investigate the construction of low-weight roofing tiles.

INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

Organization(s)	Type and Extent of Interest
Maxtile, Inc. 17141 S. Kingsview Avenue Carson, CA 90746	In the process of contacting manufacturing plants in Mexico City. Possible relocating of plant to Mexicali, Mexico.
Tasman Pulp and Paper Co., Ltd. Private Bag Kawerau New Zealand	Interest in use in the paper industry.
Several operators of geothermal power plants in Imperial Valley	Informal discussions waiting on results of research.

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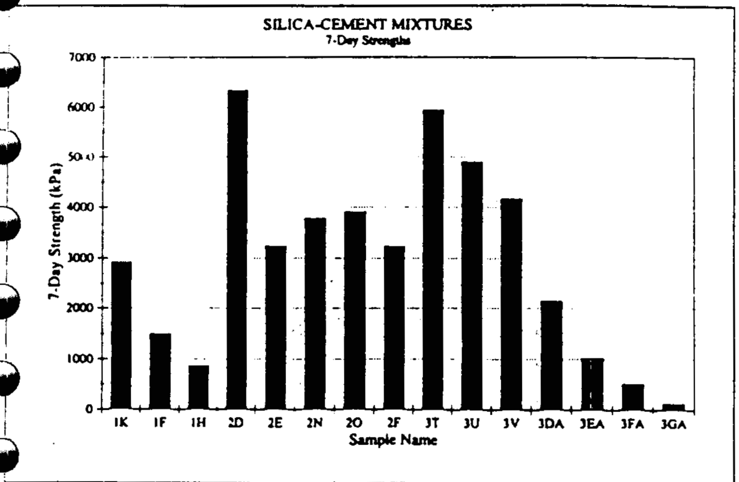


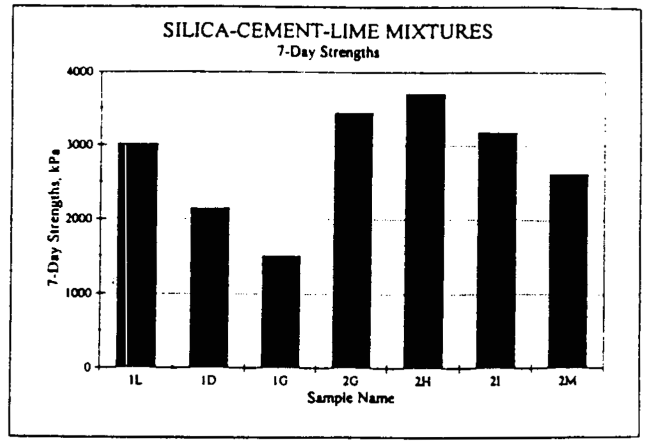
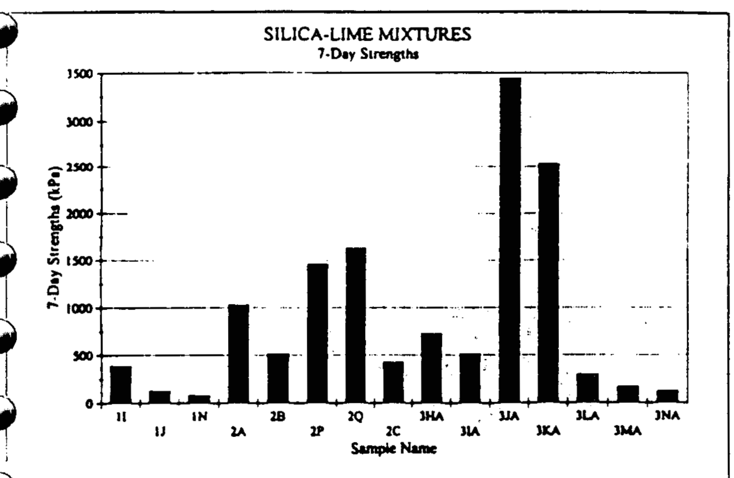


Figure 1. 7-day strength for silica-lime mixtures.

Figure 2. Flexural strengths for Samples 1 and 2.



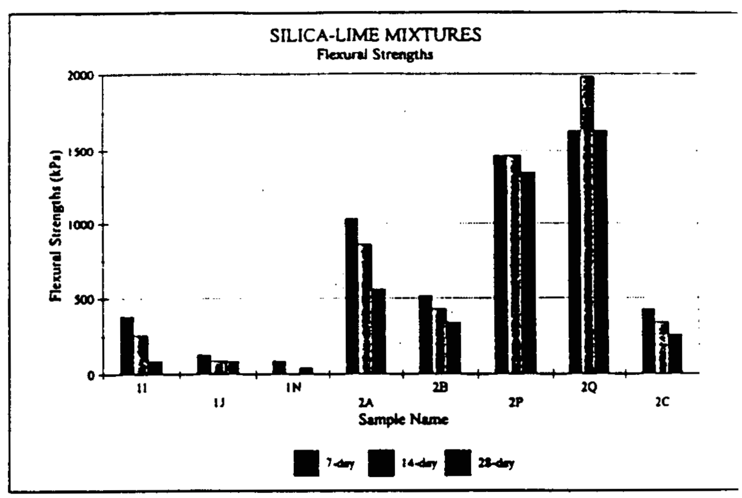


Figure 3. 7-day strength for silica-cement.

Figure 4. 7-day strength for silica-cement-lime.