SILICA WASTE UTILISATION
PHASE II - PRELIMINARY LABORATORY RESULTS

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UMMARY - A second phase of laboratory testing is being performed on waste silica from the Cerro Prieto geothermal field ı Mexico. The main objective is to produce mixes of various combinations of hydrated lime, portland cement, and plastic fibers ith the waste silica from disposal ponds to determine their suitability for use as insulating bricks in low cost housing. Silica-ement mixtures appear to have the highest flexural strength and resistance to weathering. Silica-lime mixtures appear to have ie best insulating properties (lowest thermal conductivity). The addition of plastic fibers to the silica-lime mixture appears to nprove both strength and weather resistance. Work is still in progress and will be completed in 1996 with the construction of arious test walls in the Mexicali, Mexico area.

. INTRODUCTION

he Geo-Heat Center has been investigating the stabilization f waste silica from the Cerro Prieto geothermal field for everal years (Lund et al., 1995). The main objective of the search was to combine the silica with various additives to rm bricks for low cost housing. It was found that the low ecific gravity of the silica mixtures (lime and cement) gave e bricks a high insulating value (low thermal conductivity), us having the potential of protecting a residence from high lar heating, typical of Baja California and the area around lexicali.

dditional research was performed with the silica to produce suitable road surfacing material when combined with lime, ment and asphalt.

ie Cerro Prieto geothermal field has an installed capacity 620 MW, and in the process generated 6,800 tonnes/hr of ine consisting of 5 to 6 tonnes/hr of silica. Since the othermal fields of the area extend into the Imperial Valley California where waste silica is produced from an lditional 420 MW of geothermal power generation, it is ped that this research would also be applicable to the U.S. le of the border.

RESULTS OF THE ORIGINAL RESEARCH

ie conclusions from the original research (Lund et al., 94, 1995) were that the (1) silica-lime mixtures had low ength and weather resistance, but high insulating operties, (2) addition of fibers to the silica-lime mixtures creased the strength, (3) silica-cement mixtures had high ength and weather resistance, but lower insulating values,) silica-asphalt mixtures were not suitable for road rfacing, and (5) silica-cement mixtures appeared to have plication as road surfacing material.

The main shortcoming of the original research was that the silica used 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 waste ponds for Phase II testing. This research is also funded by USDOE under a cooperative agreement between USDOE and CFE of Mexico.

3. OBJECTIVES OF THE CURRENT RESEARCH

The main objectives of the current research are to (1) produce mixes of appropriate additive and the waste silica from the disposal pond to determine their suitability for use as insulating bricks in low cost housing, and (2) field test a wall of bricks constructed from the most suitable combination of silica and additive. Additional work, not related to the silica research, is to evaluate the design of a pilot fruit dehydrator constructed at the Los Azufres geothermal field in central Mexico (Lund and Rangel, 1995).

Testing of the various mixtures was done on (1) 7.60 cm wide by 5.10 cm high by 15.2 cm long (2 in. x 3 in. x 6 in.) bricks in flexure, and (b) 5.10 cm (2 in.) cubes in compression. The testing on the cubes was later suspended due to erratic results, and only the flexural strengths used for analysis.

4. PRELIMINARY RESULTS FOR THE PHASE 11 TESTING

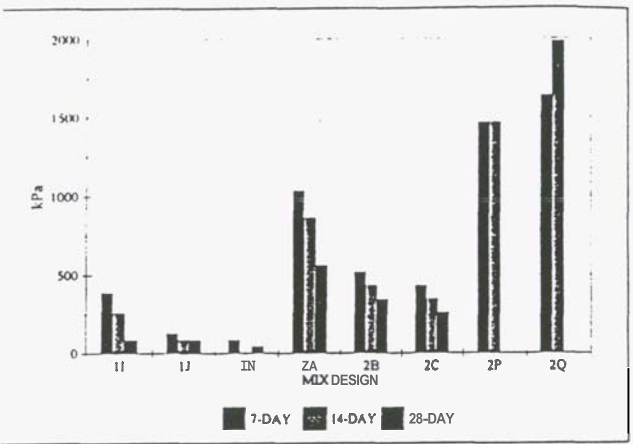
4.1 Silica

The new source of silica had a higher moisture content, more visible individual crystals, and was coarser grained that the previous material obtain from the silencer. The higher moisture content was due to the material being sampled under water in the waste ponds. The specific gravity of the silica ample was slightly lower at 2.27 vs 2.29 and appears to be omposed almost entirely of silica with no significant trace iinerals. As a result, the bricks and cubes have specific ravities that are 15 to 40 percent higher than determined in ıe previous work.

.2 Hydrated Lime

'he silica-hydrated lime mixtures again produced the lowest pecific gravity, thus indicating that they would have the best ısulating values (low thermal conductivity).

'he results of the flexural strength testing are shown in 'igure 1 The results of the previous testing (Lund et al. 1995) re labelled as " 1" and the phase II test results as "2". In the hase II testing it became apparent that there was something /rong with our testing procedure since the 14-day strengths /ere less than the 7-day strength and the 28-day strengths /ere even lower. This is contrary to results from classical :sting of lime mixtures (Transportation Research Board 'ommittee on Lime and Lime-Fly Ash Stabilization, 1987), /here strengths increase with the time of curing. This nomaly in our test results was not so evident in the original :sting (mix designs 1I, 1J and 1N in Figure 1), but is readily pparent with mix designs 2A, 2B and 2C in Figure 1.



'igure 1. **Silica-lime flexural strength results.**

)ur silica-lime mixtures were originally placed in pans sealed /ith masking tape and cured in an oven at 60° C for 7, 14 nd 28 days. Upon a detailed investigations, it appears that ur samples were drying out in the oven which prevent dequate curing and produced minute thermal cracks in the ricks. The longer the curing time the more thermal micro-racks that were produced. The samples then failed in lexure mainly along these thermal micro-cracks.

}ecause the strength of lime-stabilized soil is both time and :mperature dependent, the mixture design process in compli-ated. Curing lime stabilized samples at temperatures above bout 23° C (73° F) (considered ambient temperature) is used ɔ accelerate formation of pozzolanic reactive products and hus reduces the need for long term curing and provides an stimation of long-term strengths. However, if elevated uring 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°, 50° and 60° C is equivalent to producing 28-day 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 field curing (Transportation Research Board Committee on Lime and Lime-Fly Ash Stabilization, 1987). In addition, the vapor pressure exerted from moisture within the sample is approximately ten times higher at 60° C than at 20° C. The higher vapor pressure could also disrupt the internal structure.

Based on the above findings, two changes in our procedure were introduced (1) curing at 40° C instead of 60° C, and (2) curing in moisture-proof plastic bag instead of tape-sealed pans. The results of this revised procedure are shown 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 2P lost 40 grams of moisture during curing and sample 2Q lost only 6 grams of moisture. As is evident, the lower curing temperature produced higher strengths and the moisture-proof bag curing produced a higher strength at 14 days (the 28-day results were not available at the time of preparation of this paper). The results from mix 2Q are probably a better indication of what can be obtained in the field, providing that moist curing is achieved.

4.2 Portland Cement

Cement stabilization produced higher strengths as compared to those obtained from the original testing (Figure 2). 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 will be performed to verify this observation. Specific gravities of the samples were as much as 40 percent higher than in the original testing.

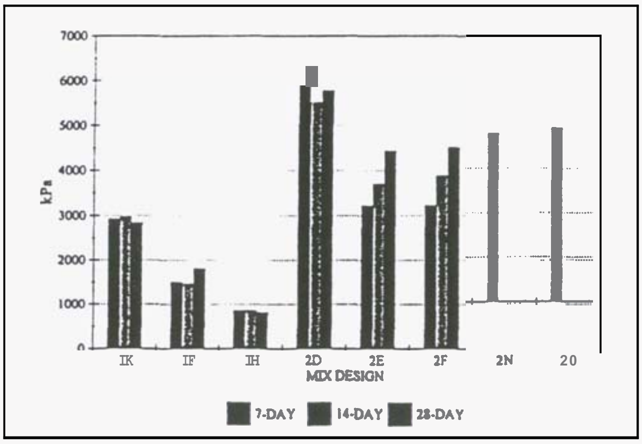


Figure 2. **Silica-cement flexural strength results.**

4.3 Portland Cement and Hydrated Lime

Results from the combined cement and lime stabilization produced strengths between those obtained for just lime and cement alone (Figure 3). The silica:cement:lime ratios of 2:1:1 (sample 2K) should be compared with either the lime or cement ratio of 1:1 (samples 2A and 2D), and the 4:1:1 (sample 2M) compared with 2:1 (samples 2B, 2E, 2N, 20, 2P and 24). There appears to be no strong advantage to using this combination of additives, unless the cost of lime is considerably less than cement, and strengths higher than those obtained from just lime stabilization are desired.

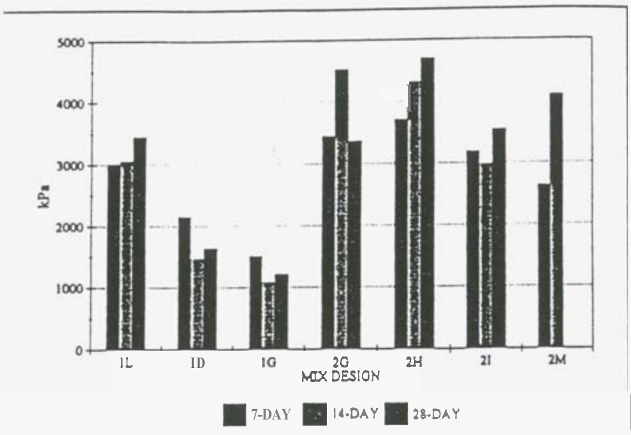


Figure 3. Silica-cement-lime flexural strength results.

4.4 Hydrated Lime and Plastic Fibers

Approximately eight grams of plastic fibers, varying between 1.4 and 2.7 percent by 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 slightly higher strength when compared with those cured at 40° C (compare Figure 4 with Figure 1). However, the fiber samples were all cured at 60° C, thus additional testing will be performed at 40° C.

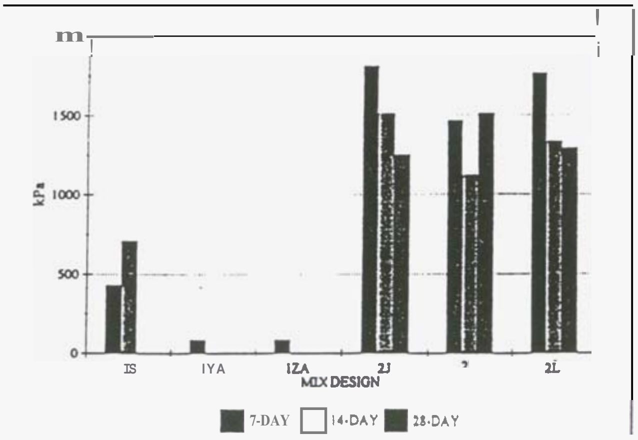


Figure 8. Silica-limefiber flexural strength results.

4.5 Sample Description

A summary of the types of samples shown in Figures 1, 2, 3 and 4 are given in Table 1. All silica-cement and silica-lime-cement samples were cured in a water bath at 25° C, and all lime and he-fiber samples were cured in an oven at 60° C, except for samples 2P and 2Q which were cured at 40" C.

Table 1. Silica Mixture Samples Description

Sample Name	Type of Sample
1D	2-Silica/1-Lime/1-Cement
1F	2-Silica/1-Cement
1G	3-Silica/1-Lime/1-Cement
1H	3-Silica/1-Cement
11	1-Silica/1-Lime
1J	2-Silica/1-Lime
1K	1-Silica/1-Cement
1L	1-Silica/1-Lime/1-Cement
1N	3-Silica/1-Lime
1s	1-Silica/1-Lime/1-Fiber
1YA	2-Silica/1-Lime/1-Fiber
1ZA	3-Silica/1-Lime/1-Fiber
2A	1-Silica/1-Lime
2B	2-Silica/1-Lime
2c	3-Silica/1-Lime
2D	1-Silica/1-Cement
2E	2-Silica/1-Cement
2F	3-Silica/1-Cement
2G	1-Silica/1-Lime/1-Cement
2H	2-Silica/1-Lime/1-Cement
21	3-Silica/1-Lime/1-Cement
2J	1-Silica/1-Lime/1-Fiber
2K	2-Silica/1-Lime/1-Fiber
2L	3-Silica/1-Lime/1-Fiber
2M	4-Silica/1-Lime/1-Cement
2N	2-Silica/1-Cement
20	2-Silica/1-Cement
2P	2-Silica/1-Lime
2Q	2-Silica/1-Lime

5. FUTURE TESTING

5.1 Thermal Conductivity

Thermal conductivity will again be determined for all oven dried samples by USGS in Menlo Park, California. Since the specific gravities are higher than those obtained from the original testing, it is predicted that the thermal conductivities will also be higher. Based on graphs developed by Lund et al. (1995) it is estimated that the silica-lime samples will have thermal conductivities above 0.36 W/m°K (specific gravities from 0.62 to 0.72), and the silica-cement will also be above 0.36 W/m °K (specific gravities from 0.79 to 1.08).

Thermal conductivities of the original silica-lime samples varied from 0.29 to 0.36 W/m OK and for the silica-cement samples from 0.34 to 0.37 W/m °K.

Even though there is an increase in specific gravities and thus a projected increase in thermal conductivities of the new samples, they values are still low enough to be promising as good insulators.

5.2 Weathering

A wet-dry weathering test was performed on the original samples. The silica-cement samples performed well (i.e. they resisted erosion of the water spray) and the silica-lime samples mostly failed, With the advent of a lower curing temperature for the silica-lime samples, thus minimizing thermal cracking, it is estimated that they will performed better.

5.3 Roofing Tiles

A lightweight roofing tile using portland cement, silica and cellulose fiber is presently being manufactured in Mexico City and sold through outlets in the U.S. under the brand name "Maxitile". Their advertised advantage is that they are lighter weight (60 percent lighter than clay or concrete tile at 20 kg/m^2). CFE is presently investigating the potential for the use of the Cerro Prieto waste silica by this manufacturer.

5.4 Percent Additives

Additional testing will be performed on reduced amounts of lime and silica additives. Testing will be performed on samples at 6.67:1 (15%), 9:1 (10%) and 19:1 (5%) silica:additive ratios. The goal is to produce an adequate (strong and resistant to weather) as well as an inexpensive brick.

6. CONCLUSIONS

The results obtain from the Phase II testing is somewhat similar to that obtained from the original testing (Lund et al., 1995). The one major testing difference is a downward revision of the silica-lime curing temperature from 60° C to 40° C. This has increased the flexural strength by improving curing conditions and reducing the thermal cracking. We also estimate that the weather resistance will also improve for the silica-lime bricks. This then makes lime stabilization a more promising additive. A minor change from the original results is an increase in the specific gravity of the samples, This is estimated to increase the thermal conductivity, but not significantly.

7. ACKNOWLEDGEMENTS

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