

FINAL REPORT

DEMONSTRATION OF SHOCK-ABSORBING CONCRETE

(SACON)

BULLET TRAP TECHNOLOGY

KENNETH L. HUDSON

MD ENVIRONMENTAL TECHNOLOGY DEMONSTRATION CENTER

U.S. ARMY ABERDEEN TEST CENTER

ABERDEEN PROVING GROUND, MD 21005-5059

GENE L. FABIAN

U.S. ARMY ENVIRONMENTAL CENTER

PHILIP G. MALONE, Ph.D.

U.S. ARMY ARMY CORPS OF ENGINEERS
WATERWAYS EXPERIMENT STATION

AUGUST 1999

1.6 Previous Testing of the Technology

The WES developed SACON as a ricochet-reducing building material for use in live-fire training facilities. Laboratory work and field use of SACON had previously been completed to determine penetration distances of various small arms into SACON of varying densities (table 1-2) (ref 12). WES utilized this information to determine appropriate densities for firing range applications.

TABLE 1-2. PENETRATION DISTANCES

Depth of Projectile Penetration in 1440-kg/m³
(90-lb/ft³) Density SACON

Weapon	Typical Depth of Penetration	
	mm	in.
0.38-caliber pistol	25.4	1.00
0.45-caliber pistol	31.7	1.25
9-mm pistol	60.5	2.38
M16A2 rifle (5.56 mm)	63.5	2.50

Ricochet test work conducted at WES determined ricochets did not pose a hazard at angles greater than 10° (ref 13). Ricochet testing at WES included a limited amount of shooting at frozen SACON. WES concluded from this limited testing that ricochet hazards were not changed by the frozen condition of SACON (ref 13).

The WES conducted laboratory testing of field samples to determine typical corrosion products that form on bullet fragments both in soil and in concrete debris (ref 1). The results showed that bullet fragments in soil typically formed lead carbonate corrosion products while fragments from SACON concrete debris formed lead hydroxide. The analysis of these field samples yielded results in agreement with previous laboratory testing (ref 1).

Utilizing these findings, WES sought to improve SACON's ability to reduce the leaching rate of lead from SACON debris (ref 14). Lead leaching is a primary consideration in determining if waste SACON debris that contains bullet fragments must be classed as a RCRA hazardous waste. If the leachate solution from the standard Toxic Characteristic Leaching Procedure (TCLP) (ref 15) contains less than 5 milligrams per liter of leachate, the waste is not considered a hazardous waste based on lead toxicity.

The lead-leaching rate is controlled by the types of corrosion products that form on the metallic lead fragments (ref 14). Typically, a lead carbonate coating will form on lead when the metal is exposed to moisture in a low-pH environment. In higher-pH (alkaline) environments, a less soluble lead hydroxide will form (ref 14).

There are additional, nearly insoluble corrosion compounds that will form on the surface of lead if phosphate is present in the liquid phase around metallic lead (ref 14). The compounds include lead phosphate hydroxide, lead phosphate chloride, and hydrated lead aluminum phosphate hydroxide (ref 14). The natural crystalline forms for these compounds and their solubility product constants are given in Table 1-3 (ref 14).

TABLE 1-3. NATURAL CRYSTALLINE FORMS

Compound	Mineral Analog	Log Solubility Product Constant
Lead carbonate ($PbCO_3$)	Cerussite	-12.8
Lead phosphate hydroxide ($Pb_5(PO_4)_3OH$)	Hydroxypyromorphite	-82.3
Lead phosphate chloride ($Pb_5(PO_4)_3Cl$)	Pyromorphite	-84.4
Basic lead aluminum phosphate ($PbAl_3(PO_4)_2(OH)_5H_2O$)	Plumbogummite	-99.3

1.6.1 Testing of the Effect of Calcium Phosphate. The addition of calcium phosphate was considered as a means to reduce the leaching rate of lead from SACON debris (ref 14). In order to test the usefulness of the proposed SACON/phosphate concrete, four test batches of SACON were prepared using the components and relative weights given in Table 1-4 (ref 14). All ingredients were dry mixed and water was added to form a workable paste. Each batch was cast in a clean plastic tray, covered with plastic film, and allowed to cure for seven days. The concrete samples were then subjected to an acid-leaching test. Each hardened sample was ground so that the material would pass a 9.5-mm (3/8-in.) sieve. Ten grams of each of the samples were placed in a covered beaker and covered with 200 mL of 0.1-N acetic acid solution. The solution was prepared by diluting reagent grade glacial acetic acid with distilled water. The initial pH of the solution was 2.1. All liquid-solid mixtures were placed on magnetic stirrers in covered beakers and were allowed to stir for 24 hours.

TABLE 1-4. COMPOSITIONS OF SACON TEST MIXTURES, g

Test Mixtures	Mixture Designation			
	Q	QP	C	CP
	CMD Sample No.			
	970291	970292	970293	970294
Portland cement Types I and II	400	400	400	400
Natural river sand (quartz, C33)	400	400	-	-
Ground limestone (calcite, C33)	-	-	400	400
Water (potable)	160	160	160	160
Tribasic calcium phosphate	-	20	-	20
Technical-grade lead powder	10	10	10	10

- Q = Quartz sand.
- QP = Quartz sand and phosphate.
- C = Calcite sand.
- CP = Calcite sand and phosphate.

The pH of each mixture was measured after 18 and 24 hours (table 1-5). All samples remained above pH 10.0. After 24 hours, the samples were centrifuged and 10 mL of the clear supernatant liquid (leachate) was collected and diluted to 100 mL using distilled water. The diluted samples were analyzed by inductively coupled atomic absorption spectrometry. The concentrations of lead in each of the leachate samples are given in Table 1-5 (ref 14).

TABLE 1-5. CONCENTRATION OF LEAD AND pH MEASUREMENTS OF ACETIC ACID LEACH LIQUIDS FROM SACON AND SACON-PHOSPHATE MIXTURES

Sample and Sample No.	Pb in Sample, ppm	Pb in Leachate, ppm	pH after 18 Hours, pH units	pH after 24 Hours, pH units
Quartz sand (Q) 70338 Chem Lab 970291 CMD	0.087	0.87	12.0	12.1
Quartz sand and phosphate (QP) 70339 Chem Lab 970292 CMD	.039	.390	10.5	11.8
Calcite sand (C) 70340 Chem Lab 970292 CMD	.031	.310	11.5	12.1
Calcite sand and phosphate (CP) 70341 Chem Lab 970294 CMD	.017	.17	11.5	11.8

1.6.2 Results of Leach Testing. The addition of calcium phosphate to the SACON formulation reduces the amount of lead leached by the 0.1-N acetic acid solution in batches containing either the natural quartz sand or the crushed limestone (calcite) sand. The lowest levels of lead were observed when both calcium phosphate and calcium carbonate were present. This mixture (CP or 970294) produced a lead level that was 20 percent of the lead level from the conventional quartz sand (Q or 970291) mixture. The results indicate that the pH alone is probably not controlling the lead solubility. The formation of an insoluble coating on the lead grains plays a role in reducing lead loss.

The results of the laboratory work were used in filing a Record of Invention by Mr. Dennis L. Bean, Dr. Charles A. Weiss Jr., Dr. Philip G. Malone (Concrete and Materials Division, Structures Laboratory, WES), and Mr. James Sigurdson (Ballastic Technology, Inc., Toronto, Ontario, Canada). The innovative formulation of SACON incorporates low-solubility calcium phosphate compounds that interact with the lead metal fragments to produce an insoluble lead phosphate coating that isolates the lead fragments, greatly reducing the tendency of the lead to dissolve in water (ref 14). The new formulation, referred to as reformulated SACON throughout this report, was manufactured and subjected to limited field testing at ATC.