national accelerator laboratory

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CHEMICAL COMPOSITION OF SOME COMMON SHIELDING MATERIALS

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In the course of shielding and radioactivation calculations, physical and chemical data for some soils and concretes were collected. They are given here because they may be useful to others.

Soil

This is the average of three samples taken close to the booster location at level 730. Following the engineering tradition, the water content is given as percentage of the dry weight, namely, if 110 lb of moist soil give 100 lb of dry soil, the water content will be given as 10% (actually 10/110 = .091). The water content in this area may be as high as 14%. Hence, the chemical composition will be given for "dry" and "moist" soils. The formula for the "moist soil" has been calculated using a conservative 10% water content.

The density of the soil is given as 90% of the undisturbed soil density. This is a common compromise between density and cost of compaction.

Portland Cement Type 1

This is an average of one year production of the Marquette Cement Co. (1967) and a typical analysis of the Lehigh Cement Co. (9/4/68).

Limestone

This is an average for samples taken from four locations near Batavia, Illinois.

Sand and Gravel

This is an average of two spot samples of sand and two of gravel from pits near Batavia, Illinois.

Iron Ore

This is a hermatite-magnetite ore from Brazil.

Ordinary Concrete

Two examples labeled "Limestone Concrete" and "Ordinary Concrete" are given. The first one is low in sodium and it was formulated for use in the booster enclosure where the sodium activation by thermalized neutrons is to be minimized. The second one is made with the gravel and sand specified in the "sand and gravel" analysis.

Table I - Composition of the limestone concrete.

Cement	520 lb/cu yd	(13.03%)
Na-free Limestone	3180 lb/cu yd	(79.70%)
Water	290 lb/cu yd	(7.27%)
Total	3990 lb/cu yd	

Note that the formulation of concretes vary

considerably even using the same aggregates depending on ultimate concrete strength. For example, Table II shows how the same coarse and fine aggregates are used to formulate three different concretes.

Table II

Strength	3000	4000	5000	lb/sq in	
Cement	442.	545.	658.	(.161)	lb/cu yd
Fine Aggregate	1363.	1218.	1112.	(.272)	lb/cu yd
Coarse Aggregate	1951.	2000.	2030.	(.496)	lb/cu yd
Water	284.	290.	292.	(.071)	lb/cu yd
Total	4040.	4053.	4092.		lb/cu yd
ρ g/cm^3	2.39	2.39	2.42		
lb/cu yd	150	151	152		

Although the density has not changed, the amount of cement has increased by 50% going from 3000 psi to 5000 psi concrete.

Heavy Concrete

The formulation is based on an aggregate of hematite and magnetite. This concrete will be used around the booster.

Ore	6364.	lb/cu yd	(88.36%)
Cement	517.	lb/cu yd	(7.18%)
Water	321.	lb/cu yd	(4.46%)
Total	7202.		
ρ = 4.27 g/cm^3		= 266 lb/cu yd	

Results

The results are given in two tables. Table III gives the elemental composition in percentage by weight. Table IV gives the number of atoms per gram of material.

TABLE III PERCENTAGES BY WEIGHT.

	DRY SØIL	MØIST SØIL	CEMENT I	LIMESTØNE
SILICØN	25.7	22.8473	9.86	1.22
ALUMINIUM	6.2	5.5118	2.83	.33
IRØN	3.27	2.90703	1.99	.6
CALCIUM	6.84	6.08076	45.57	21.5
MAGNESIUM	2.35	2.08915	1.48	12.2
SULFUR	0	0	.98	0
CARBØN	3.73	3.31597	.29	12.5
SØDIUM	.445	.395605	.39	0
PØTASSIUM	.581	.516509	.44	0
HYADRØGEN	0	1.23321	0	0
ØXYGEN	50.8	55.028	36.2	52.1

	SAND-GRAVEL	IRØN ØRE	WATER	LMNST CØNC
SILICØN	11.2	0	0	2.2571
ALUMINIUM	0	0	0	.631759
IRØN	1.68	71	0	.737497
CALCIUM	17.9	0	0	23.0759
MAGNESIUM	8.2	0	0	9.91624
SULFUR	0	0	0	.127694
CARBØN	9.47	0	0	10.0003
SØDIUM	0	0	0	.050817
PØTASSIUM	0	0	0	.057332
HYADRØGEN	0	0	11.11	.79992
ØXYGEN	51.3	29	88.89	52.6406

	HEAVY CØNCRETE	ØRD-CØNCRETE		
SILICØN	.757948	10.1891	0	0
ALUMINIUM	.203194	.45563	0	0
IRØN	62.8785	1.61063	0	0
CALCIUM	3.27336	21.0872	0	0
MAGNESIUM	.106264	6.53588	0	0
SULFUR	.070364	.15773	0	0
CARBØN	.020822	7.31965	0	0
SØDIUM	.028002	.06279	0	0
PØTASSIUM	.031592	.07084	0	0
HYADRØGEN	[illegible]	[illegible]	0	0

TABLE IV ATØMS PER GRAM.

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	DRY SØIL	MØIST SØIL	CEMENT I	LIMESTØNE
SILICØN	5.51054E+21	4.89887E+21	2.11416E+21	2.61520E+20
ALUMINIUM	1.38403E+21	1.23045E+21	6.31768E+20	7.36690E+19
IRØN	3.52645E+20	3.13501E+20	2.14606E+20	6.47055E+19
CALCIUM	1.02788E+21	9.13783E+20	6.85101E+21	3.23090E+21
MAGNESIUM	5.82232E+20	5.17604E+20	3.66682E+20	3.02265E+21
SULFUR	0	0	1.84 E+20	0
CARBØN	1.87059E+21	1.66295E+21	1.45435E+20	6.26873E+21
SØDIUM	1.16583E+20	1.03642E+20	1.02174E+20	0
PØTASSIUM	8.94978E+19	7.95635E+19	6.77780E+19	0
HYADRØGEN	0	7.37 E+21	0	0
ØXYGEN	1.91230E+22	2.07146E+22	1.36270E+22	1.96124E+22

	SAND-GRAVEL	IRØN ØRE	WATER	LMNST CØNC
SILICØN	2.40148E+21	0	0	4.84 E+20
ALUMINIUM	0	0	0	1.41 E+20
IRØN	1.81 E+20	7.66 E+21	0	7.95 E+19
CALCIUM	2.69 E+21	0	0	3.47 E+21
MAGNESIUM	2.03 E+21	0	0	2.46 E+21
SULFUR	0	0	0	2.40 E+19
CARBØN	4.74919E+21	0	0	5.02 E+21
SØDIUM	0	0	0	1.33 E+19
PØTASSIUM	0	0	0	8.83 E+18
HYADRØGEN	0	0	6.64 E+22	4.78 E+21
ØXYGEN	1.93 E+22	1.09 E+22	3.35 E+22	1.98 E+22

	HEAVY CØNCRETE	ØRD-CØNCRETE		
SILICØN	1.51797E+20	2.18472E+21	0	0
ALUMINIUM	4.53609E+19	1.01715E+20	0	0
IRØN	6.78097E+21	1.73694E+20	0	0
CALCIUM	4.91903E+20	3.16887E+21	0	0
MAGNESIUM	2.63278E+19	1.61932E+21	0	0
SULFUR	1.32190E+19	2.96416E+19	0	0
CARBØN	1.04422E+19	3.67080E+21	0	0
SØDIUM	7.33606E+18	1.64499E+19	0	0
PØTASSIUM	4.86646E+18	1.09123E+19	0	0
HYADRØGEN	2.96075E+21	4.71330E+21	0	0
ØXYGEN	1.21168E+22	1.94008E+22	0	0