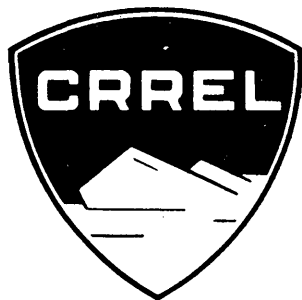


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**DIRECT SHEAR STUDY ON SNOW**  
**PROCEDURE AND DATA**

by  
G. E. H. Ballard, E. D. Feldt  
and  
S. R. Toth

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U.S. ARMY MATERIEL COMMAND  
COLD REGIONS RESEARCH & ENGINEERING LABORATORY  
HANOVER, NEW HAMPSHIRE



# DIRECT SHEAR STUDY ON SNOW - PROCEDURE AND DATA

by

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## Introduction

In order to gain a greater insight into the behavior of snow and to provide a body of data for the purpose of checking theoretical developments in snow mechanics, a direct shear experiment was performed on a standardized disaggregated snow, investigating the effect of porosity, age-hardening time, normal stress, and temperature on the shear strength. Incidental to the direct shear test, consolidation, frictional resistance, and strain data were recorded.

This report describes the experimental procedure, and provides the data obtained from the experiment.

## Test equipment

Snow molds (Fig. 1) constructed from standard fir plywood were used to prepare the large number of samples needed in the experiment. A hot wire cutter (Fig. 2), consisting of approximately 60 cm of 0.4 mm Nichrome wire connected to a 20-volt source, was used to cut the samples to the size required for the tests.

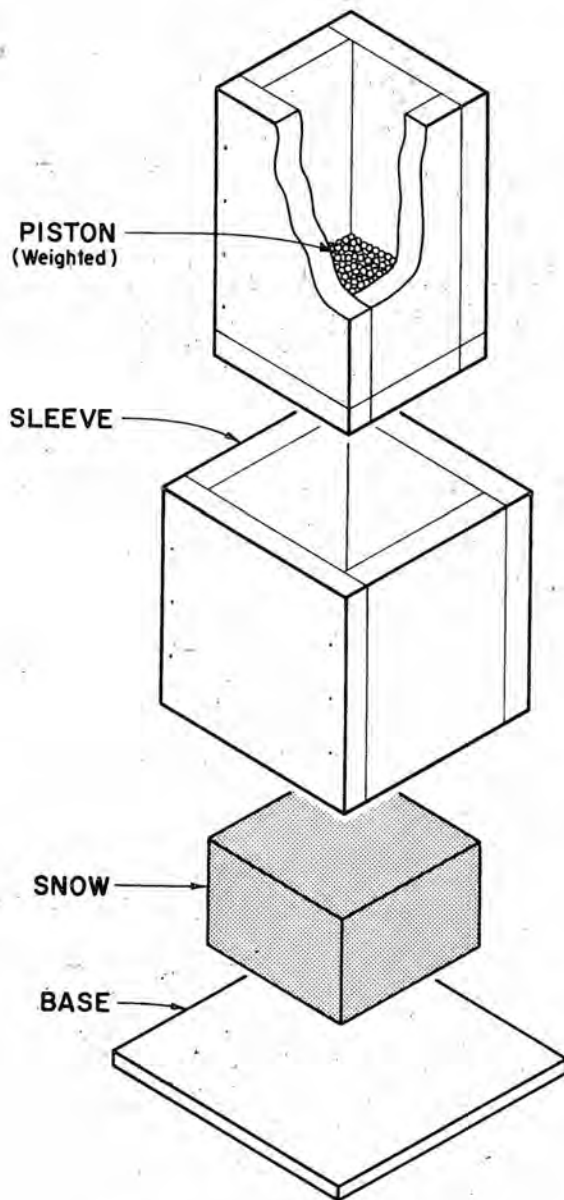


Figure 1. Snow mold.

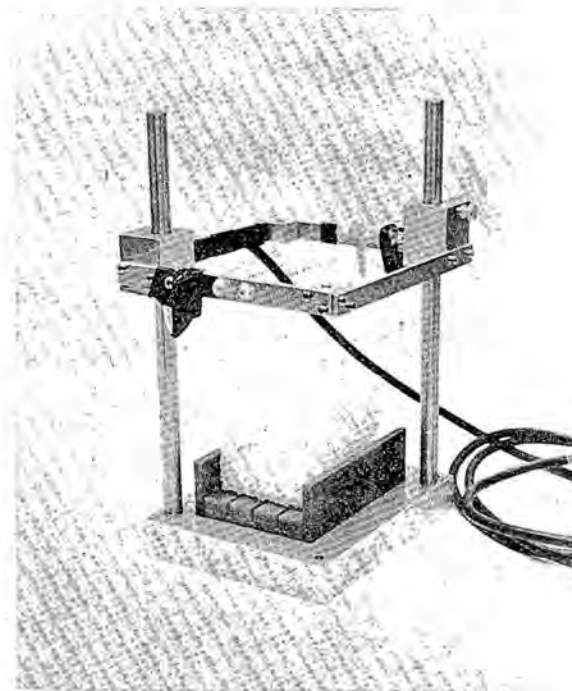


Figure 2. Hot wire cutter.

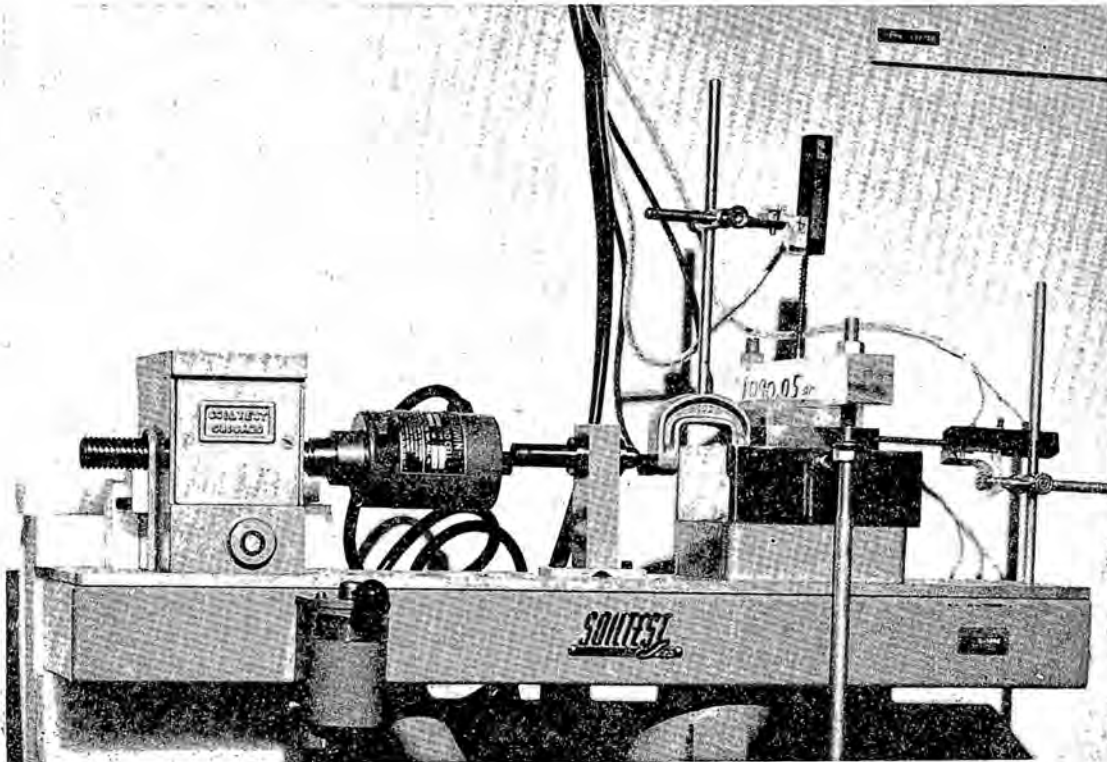


Figure 3. Direct shear test apparatus.

Testing was done in a motorized direct shear test apparatus (Fig. 3) calibrated at test temperatures and modified as follows\*: the proving ring was replaced by a 1000-lb SR-4 Baldwin load cell; the dial indicators were replaced by linear potentiometers; the shearing force and the vertical and horizontal displacements were recorded on Leeds and Northrup X-Y recorders; and special stainless-steel sample grips (tooth height 2 mm), and aluminum loading and supporting blocks (Fig. 4) were fabricated.

#### Test material

Freshly fallen snow was collected in the vicinity of USA CRREL during the winter of 1963-64. The snow was stored at  $-10^{\circ}\text{C}$  for 10 days and then stored at  $-30^{\circ}\text{C}$  until used to prepare the samples. Sieve analyses were performed periodically. The results appear in Table I.

Samples were prepared at temperatures of  $-3.3$ ,  $-6.7$ , and  $-10^{\circ}\text{C}$ . Snow from storage was brought to the preparation temperature, disaggregated through a No. 12 U. S. sieve (1.68 mm), and allowed to freefall approximately 30 cm into a sample mold. The snow was scraped level with the top of the mold, and the "initial" porosity of the sample was determined.

One of the following consolidating loads — 0.01, 0.02, 0.05, 0.2, or 0.5  $\text{kg}/\text{cm}^2$  — was then applied by means of a weighted piston (Fig. 1). A series of samples for each load were allowed to consolidate and age-hardened for times

\*Modification and Instrumentation of Soiltest Direct Shear Apparatus, by W. Wolff and G. Ballard, Unpublished Technical Note, April 1964.

Table I. Sieve analysis of test material.

Time after collection (days)	Uniformity coefficient	Weight percent passing				
		#12 (1.68 mm)	#18 (1.00 mm)	#30 (0.590 mm)	#60 (0.250 mm)	#120 (0.125 mm)
6	1.87	100	80	39	1	0
6	1.87	100	85	41	1	0
10	2.17	100	76	30	1	0
10	1.91	100	73	32	1	0
40	2.08	100	76	38	2	0
40	2.38	100	69	31	1	0
40	1.97	100	80	41	2	0
70	1.92	100	83	43	2	0
100	2.00	100	80	43	3	0
145	1.87	100	84	38	1	0
165	1.89	100	81	37	2	0
198	2.00	100	80	41	3	0
233	2.09	100	67	25	3	0

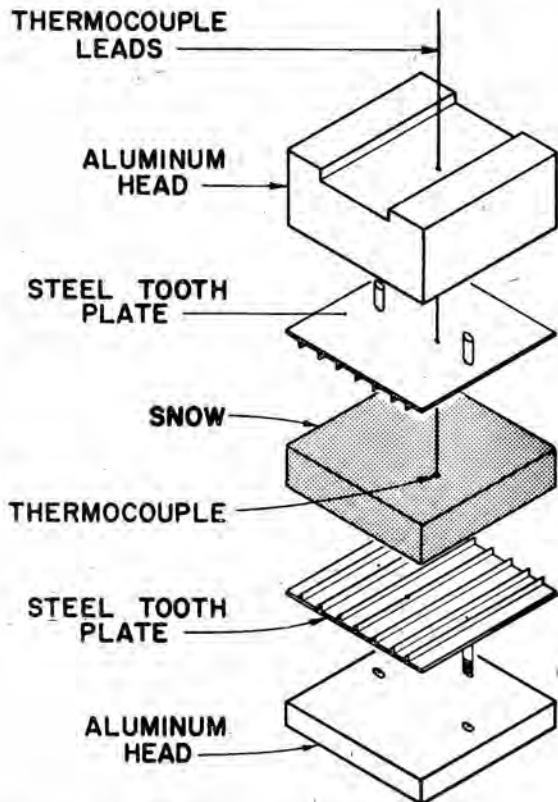


Figure 4. Sample grip assembly.

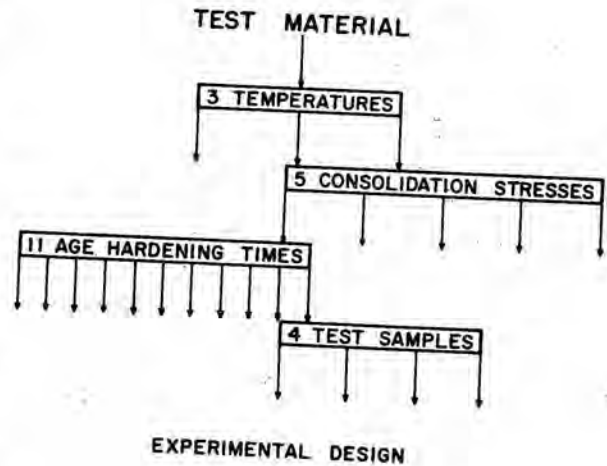


Figure 5. Experimental design.

ranging from 1 to 1100 hours at the preparation temperature. At the end of the age-hardening period the "test" porosity was determined. The sample was then removed from the mold, cut into four individual test samples of 1.9 cm thickness with the hot wire cutter, and trimmed to 7.6 cm square. The direction of cutting was parallel to the direction of the consolidating force. Figure 5 shows the experimental design of the sample preparation.

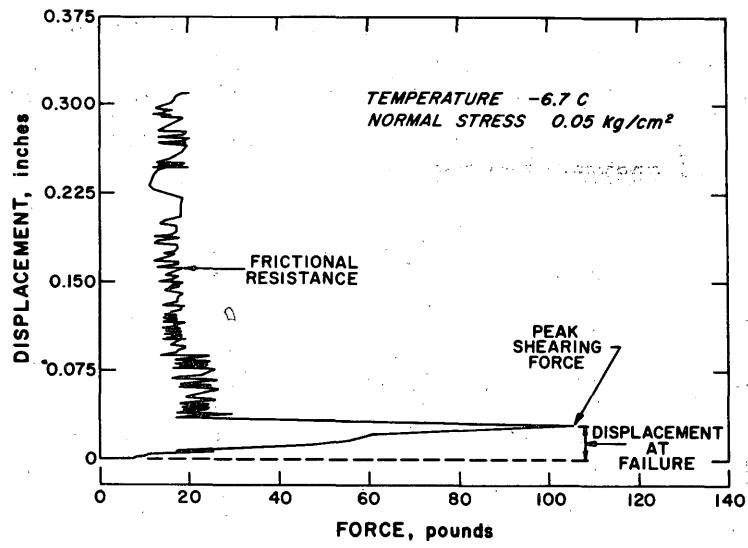


Figure 6. Reproduction of X-Y recorder graph of a low normal load test.

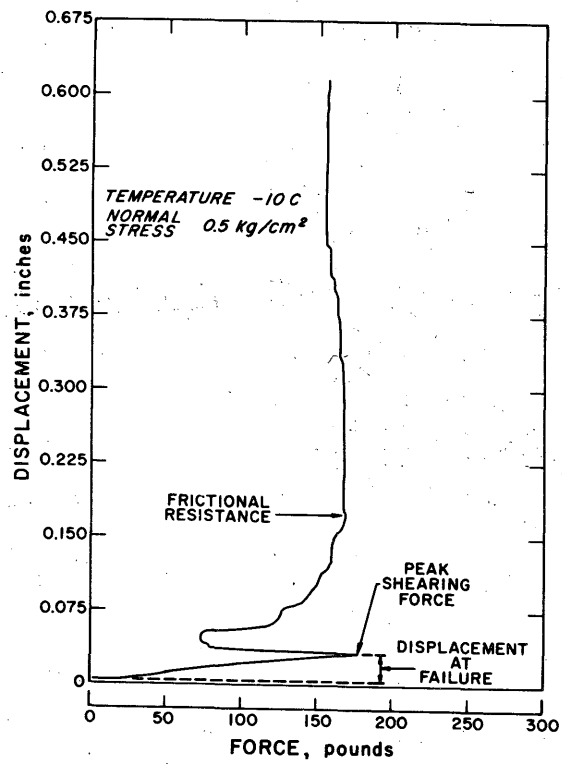


Figure 7. Reproduction of X-Y recorder graph of a high normal load test.

### Test procedure

During the testing of samples the temperature of the laboratory was maintained at the respective age-hardening temperature. Heat introduced to the sample during cutting was allowed to dissipate before testing proceeded. The bottom stainless-steel grip (Fig. 4) was warmed slightly on a hot plate and implanted in the sample. The aluminum supporting block, cooled below the test temperature on a cold plate, was immediately fastened snugly to the back of the grip plate to remove the excess heat. The sample was placed in the lower half of the shear box, the upper half of the shear box was positioned, and the upper grip plate (heated) and aluminum loading block (cooled) were fitted. A thermocouple was inserted through the small holes in the loading block and the grip plate to the center of the test specimen to determine if the temperature of the specimen was near the laboratory temperature.

A normal stress, equal and perpendicular in direction to the stress used to consolidate the sample, was applied to the loading block; and the shearing force was then immediately applied to the test specimen at a constant rate of shearing displacement of 0.03 cm/sec. Several tests were performed at different shearing displacement rates; the results are presented in Table II.

Immediately after the test the shear box was separated, and the thermocouple was inserted into the sample near the failure zone to measure the "test" temperature.

Figures 6 and 7 represent typical charts from the X-Y recorder, and show how the forces used to calculate the "peak strength" and "frictional resistance" were selected, as well as the measurement of "displacement at failure". The frictional force was picked for a displacement of 4 mm and the frictional resistance reported in the data is corrected for the reduced area of contact. Table III contains the direct shear and incidental data obtained in this experiment.

### Discussion

Analysis of this data is progressing simultaneously with theoretical developments in the mechanics of snow. Interested readers are referred to USA CRREL Research Reports 181 "An Approach to the Consolidation of Snow" and 184 "Consideration of the Strength of Snow" (in preparation).

Table II. Tests at different strain rates. Normal load .02 kg/cm<sup>2</sup>. Temperature of age hardening -10C.

Exp. no.	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Test porosity (dimensionless)	Aging time (hours)	Test temp (°C)	Strain rate (cm/sec)
861	0.300	0.139	0.021	0.586	4367	6.1	0.01
918	0.521	0.221	0.059	0.570	4488	6.4	0.01
925	0.656	0.115	0.046	0.583	4505	6.4	0.01
932	0.569	0.262	0.076	0.567	4510	6.7	0.01
Ave.	0.512	0.184	0.051	0.577	4467	6.4	0.01
878	0.687	0.082	0.118	0.551	4440	6.8	0.02
898	0.600	0.164	0.099	0.569	4464	6.3	0.02
928	1.082	0.328	0.042	0.562	4505	6.7	0.02
929	0.395	0.205	0.029	0.590	4505	6.7	0.02
Ave.	0.691	0.195	0.072	0.568	4478	6.5	0.02
859	0.348	0.066	0.025	0.586	4367	6.3	0.03
916	0.332	0.082	0.061	0.570	4488	6.3	0.03
923	0.474	0.123	0.084	0.583	4505	6.0	0.03
933	0.656	0.123	0.044	0.567	4510	6.3	0.03
Ave.	0.453	0.240	0.054	0.577	4467	6.2	0.03
879	0.435	0.164	0.092	0.551	4440	6.3	0.04
899	0.830	0.115	0.063	0.569	4464	6.3	0.04
926	0.593	0.090	0.103	0.562	4505	6.5	0.04
930	0.379	0.090	0.032	0.590	4505	6.4	0.04
Ave.	0.559	0.115	0.073	0.568	4478	6.4	0.04
860	0.482	0.115	0.071	0.586	4367	5.8	0.05
917	0.411	0.066	0.074	0.570	4488	6.4	0.05
924	0.553	0.139	0.046	0.583	4505	6.1	0.05
934	0.427	0.107	0.013	0.567	4510	6.4	0.05
Ave.	0.468	0.107	0.051	0.577	4467	6.2	0.05
880	0.569	0.139	0.052	0.551	4440	6.3	0.06
897	0.435	0.065	0.082	0.569	4464	6.3	0.06
927	0.672	0.065	0.023	0.562	4505	6.4	0.06
931	0.292	0.082	0.042	0.590	4505	6.1	0.06
Ave.	0.492	0.088	0.050	0.568	4478	6.3	0.06

Table III.

DIRECT SHEAR DATA							DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec							Constant strain rate 0.03 cm/sec						
Peak strength (g/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -3.33C							Temperature of age hardening -3.33C						
Normal load 0.01 kg/cm <sup>2</sup>							Normal load 0.02 kg/cm <sup>2</sup>						
.058	.047	.015	.586	.576	1	3.3	.034	.027	.008	.573	.542	1	3.3
.025	.037	.010	.586	.576	1	3.0	.042	.034	.000	.573	.542	1	3.3
.040	.051	.029	.586	.576	1	2.7	.024	.031	.004	.573	.542	1	3.2
.085	.039	.065	.586	.576	1	3.5	.087	.033	.013	.573	.542	1	3.4
.041	.025	.000	.567	.553	2	3.4	.047	.048	.000	.575	.542	2	2.8
.064	.028	.002	.567	.553	2	3.2	.121	.066	.042	.575	.542	2	3.9
.091	.031	.000	.567	.553	2	3.1	.058	.049	.004	.575	.542	2	2.8
.086	.042	.015	.567	.553	2	3.5	.081	.049	.023	.575	.542	2	3.7
.073	.034	.013	.574	.567	4	3.4	.095	.046	.029	.546	.519	4	3.5
.094	.039	.000	.574	.567	4	3.2	.073	.051	.013	.546	.519	4	3.2
.073	.041	.019	.574	.567	4	3.4	.093	.043	.006	.546	.519	4	3.0
.028	.025	.000	.574	.567	4	4.0	.098	.059	.017	.546	.519	4	3.9
.056	.037	.000	.590	.585	17.5	3.4	.140	.059	.049	.547	.521	7	3.1
.062	.033	.019	.590	.585	17.5	3.7	.134	.054	.066	.547	.521	7	3.4
.090	.043	.011	.590	.585	17.5	3.1	.153	.063	.038	.547	.521	7	3.0
.081	.041	.013	.590	.585	17.5	3.7	.077	.067	.019	.547	.521	7	3.3
.107	.048	.008	.566	.554	31	3.5	.112	.086	.040	.604	.562	16	3.4
.140	.051	.023	.566	.554	31	3.1	.110	.081	.046	.604	.562	16	3.4
.126	.046	.032	.566	.554	31	3.3	.126	.100	.019	.604	.562	16	3.3
.130	.043	.050	.566	.554	31	3.0	.150	.063	.025	.604	.562	16	3.6
.123	.038	.006	.554	.542	72	2.3	.182	.049	.006	.598	.566	30	3.8
.245	.060	.090	.554	.542	72	3.5	.124	.053	-	.598	.566	30	3.2
.318	.066	.086	.554	.542	72	3.4	.112	.074	.002	.598	.566	30	3.8
.103	.049	.038	.554	.542	72	3.3	.077	.035	.019	.598	.566	30	3.2
.108	.056	.040	.559	.545	139	2.4	.302	.068	.043	.558	.522	74	3.0
.174	.090	.038	.559	.545	139	3.3	.246	.094	.029	.558	.522	74	2.8
.253	.057	.044	.559	.545	139	3.5	.363	.082	.050	.558	.522	74	3.2
.177	.084	.048	.559	.545	139	3.0	.359	.084	.052	.558	.522	74	3.3
.191	.068	.057	.583	.564	281	3.4	.332	.121	.050	.553	.515	140	3.4
.424	.082	.069	.583	.564	281	3.3	.344	.067	.003	.553	.515	140	3.2
.514	.106	.019	.583	.564	281	3.4	.371	.115	.042	.553	.515	140	3.0
.354	.087	.076	.583	.564	281	3.3	.536	.073	.057	.553	.515	140	3.0
.307	.074	.046	.566	.537	576	2.9	.344	.103	.055	.592	.551	282	3.4
.620	.074	.078	.566	.537	576	2.9	.672	.193	.071	.592	.551	282	3.2
.368	.071	.042	.566	.537	576	3.3	.520	.102	.090	.592	.551	282	3.6
.382	.065	.076	.566	.537	576	3.1	.282	.094	.099	.592	.551	282	3.5
.561	.066	.094	.590	.516	1152	3.5	.365	.131	.029	.573	.503	574	3.0
.608	.057	.096	.590	.516	1152	3.5	.478	.105	.052	.573	.503	574	3.4
.654	.123	.052	.590	.516	1152	3.4	.593	.212	.036	.573	.503	574	3.7
.468	.082	.055	.590	.516	1152	3.0	.462	.164	.029	.573	.503	574	3.3
							.569	.123	.086	.566	.499	1147	3.1
							.591	.131	.074	.566	.499	1147	3.0
							.623	.148	.064	.566	.499	1147	3.1
							.652	.123	.048	.566	.499	1147	3.5



Table III (Cont.).

DIRECT SHEAR DATA							DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec							Constant strain rate 0.03 cm/sec						
Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -3.33C							Temperature of age hardening -3.33C						
Normal load 0.05 kg/cm <sup>2</sup>							Normal load 0.2 kg/cm <sup>2</sup>						
.095	.082	.004	.551	.507	1	3.7	.320	.324	.015	.509	.467	1	2.8
.079	.071	.032	.551	.507	1	3.5	.344	.357	.011	.509	.467	1	3.3
.071	.072	.002	.551	.507	1	3.4	.351	.312	.034	.509	.467	1	3.5
.073	.062	.004	.551	.507	1	4.5	.313	.350	.010	.509	.467	1	3.3
.140	.125	.002	.558	.475	2	3.1	.297	.312	.029	.569	.437	2	3.4
.130	.079	.013	.558	.475	2	3.1	.379	.312	.048	.569	.437	2	3.6
.107	.084	.002	.558	.475	2	3.5	.302	.341	.006	.569	.437	2	3.5
.103	.093	.004	.558	.475	2	3.6	.392	.341	.032	.569	.437	2	3.3
.087	.078	.000	.553	.495	4	3.0	.387	.287	.029	.544	.449	4	3.3
.109	.092	.000	.553	.495	4	3.0	.319	.312	.004	.544	.449	4	3.2
.117	.098	.006	.553	.495	4	3.0	.387	.349	.053	.544	.449	4	3.5
.103	.094	.008	.553	.495	4	3.1	.327	.328	.040	.544	.449	4	3.4
.213	.116	.034	.542	.482	7	3.1	.506	.476	.008	.542	.421	7	3.2
.191	.107	.036	.542	.482	7	3.2	.596	.476	.046	.592	.421	7	3.2
.219	.135	.038	.542	.482	7	3.4	.348	.344	.000	.542	.421	7	3.4
.156	.090	.025	.542	.482	7	3.5	.308	.352	.038	.542	.421	7	3.4
.170	.089	.017	.520	.521	16	4.0	.556	.313	.053	.590	.459	17	3.2
.284	.107	.011	.570	.521	16	3.8	.381	.344	.038	.590	.459	17	3.4
.209	.103	.019	.570	.521	16	4.0	.679	.303	.076	.590	.459	17	3.1
.161	.101	.031	.570	.521	16	3.7	.447	.295	.040	.590	.459	17	3.1
.212	.111	.048	.569	.504	30	3.0	.442	.484	.029	.566	.436	31	3.0
.241	.111	.011	.569	.504	30	3.0	.980	.394	.090	.566	.436	31	3.3
.237	.103	.029	.569	.504	30	3.0	.924	.467	.076	.566	.436	31	3.4
.118	.089	.019	.569	.504	30	3.0	.695	.362	.042	.566	.436	31	3.4
.316	.148	.050	.577	.509	77	3.2	.858	.558	.046	.640	.519	73	2.9
.449	.159	.034	.577	.509	77	3.6	.569	.541	.015	.640	.519	73	3.3
.515	.138	.076	.577	.509	77	2.7	.782	.754	.073	.640	.519	73	3.6
.544	.148	.057	.577	.509	77	3.3	.743	.582	.053	.640	.519	73	3.3
.395	.148	.046	.566	.490	142	3.1	1.150	.476	.086	.615	.491	143	3.3
.387	.181	.046	.566	.490	142	2.8	1.198	.459	.038	.615	.491	143	3.0
.562	.094	.065	.566	.490	142	3.5	.717	.594	.038	.615	.491	143	3.5
.403	.133	.057	.566	.490	142	3.0	.853	.508	.067	.615	.491	143	3.6
.194	.095	.065	.595	.490	285	2.8	.995	.492	.071	.588	.481	308	3.2
.300	.090	.092	.595	.490	285	3.3	.830	.549	.029	.588	.481	308	3.1
.326	.083	.099	.595	.490	285	3.0	.972	.394	.025	.588	.481	308	3.2
.412	.080	.036	.595	.490	285	3.1	.656	.451	.034	.588	.481	308	3.2
.942	.164	.067	.566	.463	572	3.5	1.146	.640	.078	.589	.425	566	2.9
.782	.112	.080	.566	.463	572	3.5	1.177	.451	.096	.589	.425	566	3.6
.787	.148	.096	.566	.463	572	3.5	1.280	.590	.034	.589	.425	566	3.6
.932	.125	.120	.566	.463	572	3.6	1.359	.656	.115	.589	.425	566	3.3
.735	.172	.053	.570	.486	1152	3.2	.989	.708	.032	.631	.481	1147	2.9
.806	.123	.097	.570	.486	1152	3.0	.972	.524	.044	.631	.481	1147	3.2
.011	.205	.134	.570	.486	1152	3.0	1.015	.616	.011	.631	.481	1147	3.5
.995	.246	.092	.570	.486	1152	3.0	.731	.506	.023	.631	.481	1147	3.4

Table III (Cont.).

DIRECT SHEAR DATA							DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec							Constant strain rate 0.03 cm/sec						
Peak strength (g/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -3.33C							Temperature of age hardening -6.67C						
Normal load 0.5 kg/cm <sup>2</sup>							Normal load 0.01 kg/cm <sup>2</sup>						
545	.754	.038	.571	.434	1	1.5	0.040	0.029	0.004	0.545	0.544	1	6.0
616	.656	.040	.571	.434	1	3.5	0.052	0.041	0.002	0.545	0.544	1	5.6
593	.574	.046	.571	.434	1	3.4	0.024	0.021	0.000	0.545	0.544	1	6.0
537	.607	.029	.571	.434	1	3.3	0.039	0.030	0.002	0.545	0.544	1	5.9
593	.746	.011	.549	.480	2	2.7	0.021	0.024	0.000	0.575	0.571	2	5.8
751	.738	.059	.549	.480	2	3.5	0.025	0.035	0.000	0.575	0.571	2	6.0
711	.656	.038	.549	.480	2	3.3	0.037	0.025	0.000	0.575	0.571	2	5.2
585	.656	.031	.549	.480	2	3.3	0.070	0.025	0.002	0.575	0.571	2	6.1
703	.664	.032	.576	.418	4	3.5	0.071	0.043	0.006	0.559	0.553	4	6.3
814	.836	.038	.576	.418	4	3.4	0.051	0.030	0.019	0.559	0.553	4	6.0
929	1.046	.036	.576	.418	4	3.1	0.085	0.053	0.006	0.559	0.553	4	7.0
125	.763	.057	.576	.418	4	3.1	0.029	0.033	0.002	0.559	0.553	4	6.4
746	.705	.057	.554	.437	7	3.3	0.044	0.036	0.010	0.574	0.564	7	6.4
845	.620	.025	.554	.437	7	3.1	0.079	0.046	0.008	0.574	0.564	7	5.6
019	.746	.027	.554	.437	7	3.1	0.085	0.041	0.010	0.574	0.564	7	6.0
980	.910	.038	.554	.437	7	3.4	0.100	0.051	0.004	0.574	0.564	7	6.5
830	.804	.038	.577	.443	16	3.4	0.085	0.057	0.000	0.535	0.532	16	6.0
569	.582	.019	.577	.443	16	3.2	0.052	0.049	0.000	0.535	0.532	16	5.9
711	.574	.027	.577	.443	16	3.4	0.097	0.033	0.008	0.535	0.532	16	6.0
687	.656	.015	.577	.443	16	3.3	0.171	0.053	0.015	0.535	0.532	16	6.0
003	.681	.057	.567	.509	31	3.1	0.048	0.043	0.004	0.563	0.557	31	6.3
948	.681	.057	.567	.509	31	3.1	0.132	0.049	0.002	0.563	0.557	31	6.7
138	.722	.057	.567	.509	31	3.5	0.120	0.062	0.038	0.563	0.557	31	6.0
964	.730	.061	.567	.509	31	3.4	0.097	0.054	0.017	0.563	0.557	31	6.0
529	.713	.025	.615	.502	77	3.1	0.152	0.082	0.010	0.581	0.573	72	6.4
830	.713	.038	.615	.502	77	3.0	0.129	0.090	0.023	0.581	0.573	72	6.3
719	.804	.038	.615	.502	77	3.1	0.237	0.074	0.021	0.563	0.551	73	6.1
288	.861	.044	.615	.502	77	3.0	0.176	0.060	0.046	0.563	0.551	73	6.0
248	1.271	.013	.627	.439	141	2.5	0.207	0.072	0.053	0.552	0.545	144	6.9
011	.836	.019	.627	.439	141	2.5	0.201	0.078	0.015	0.552	0.545	144	6.9
343	1.066	.036	.627	.439	141	2.2	0.161	0.088	0.027	0.552	0.545	144	6.9
627	.935	.067	.627	.439	141	3.5	0.190	0.079	0.032	0.552	0.545	144	6.9
398	1.107	.044	.615	.437	308	3.1	0.482	0.078	0.074	0.525	0.516	289	6.0
098	.886	.025	.615	.437	308	2.4	0.198	0.066	0.042	0.525	0.516	289	5.7
280	1.279	.036	.615	.437	308	3.0	0.339	0.086	0.013	0.525	0.516	289	6.0
146	1.132	.063	.615	.437	308	1.5	0.286	0.098	0.019	0.525	0.516	289	6.0
861	1.099	.038	.579	.409	556	3.1	0.253	0.107	0.048	0.601	0.581	575	5.4
999	1.181	.118	.579	.409	556	2.0	0.435	0.123	0.031	0.601	0.581	575	5.4
485	1.017	.076	.579	.409	556	3.0	0.316	0.069	0.061	0.601	0.581	575	5.2
185	1.148	.063	.579	.409	556	3.0	0.332	0.095	0.025	0.601	0.581	575	5.1
723	1.945	.059	.610	.359	1150	3.3	0.190	0.057	0.048	0.569	0.558	1146	6.0
525	1.602	.023	.610	.359	1150	3.5	0.561	0.082	0.080	0.569	0.558	1146	6.2
822	1.487	.048	.610	.359	1150	2.9	0.292	0.115	0.031	0.569	0.558	1146	6.2
752	1.092	.029	.610	.359	1150	3.1	0.348	0.084	0.053	0.569	0.558	1146	6.1

Table III (Cont.).

DIRECT SHEAR DATA							DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec							Constant strain rate 0.03 cm/sec						
Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -6.67C							Temperature of age hardening -6.67C						
Normal load 0.02 kg/cm <sup>2</sup>							Normal load 0.05 kg/cm <sup>2</sup>						
052	0.029	0.002	0.566	0.555	1	6.3	0.083	0.080	0.032	0.564	0.539	1	6.4
071	0.046	0.000	0.566	0.555	1	6.0	0.083	0.070	0.002	0.564	0.539	1	6.4
044	0.044	0.002	0.566	0.555	1	6.5	0.071	0.059	0.000	0.564	0.539	1	6.2
059	0.048	0.013	0.566	0.555	1	6.4	0.046	0.081	0.000	0.564	0.539	1	6.4
040	0.041	0.010	0.559	0.543	2	6.4	0.062	0.079	0.008	0.544	0.528	2	6.4
040	0.041	0.002	0.559	0.543	2	6.2	0.080	0.074	0.002	0.544	0.528	2	6.2
079	0.047	0.036	0.559	0.543	2	6.4	0.087	0.078	0.019	0.544	0.528	2	6.2
119	0.049	0.006	0.559	0.543	2	6.3	0.099	0.090	0.025	0.544	0.528	2	6.2
055	0.043	0.002	0.532	0.523	4	6.1	0.073	0.089	0.019	0.526	0.518	4	6.4
104	0.065	0.004	0.532	0.523	4	6.5	0.079	0.074	0.002	0.526	0.518	4	6.0
085	0.056	0.002	0.532	0.523	4	6.2	0.101	0.076	0.006	0.526	0.518	4	6.4
065	0.064	0.002	0.532	0.523	4	6.2	0.077	0.070	0.004	0.526	0.518	4	6.2
113	0.066	0.015	0.547	0.533	7	6.3	0.087	0.089	0.011	0.533	0.520	7	7.2
119	0.049	0.011	0.547	0.533	7	6.0	0.093	0.084	0.004	0.533	0.520	7	6.3
058	0.049	0.004	0.547	0.533	7	6.1	0.074	0.083	0.002	0.533	0.520	7	6.2
100	0.062	0.006	0.547	0.533	7	6.2	0.128	0.078	0.031	0.533	0.520	7	6.4
041	0.062	0.002	0.616	0.535	17	6.5	0.134	0.123	0.000	0.522	0.537	17	6.0
112	0.070	0.006	0.616	0.535	17	6.0	0.113	0.105	0.000	0.522	0.537	17	5.6
092	0.060	0.025	0.616	0.535	17	6.3	0.132	0.062	0.006	0.552	0.537	17	5.8
133	0.056	0.017	0.616	0.535	17	6.2	0.063	0.065	0.000	0.552	0.537	17	5.8
103	0.068	0.000	0.555	0.546	31	6.7	0.188	0.112	0.029	0.531	0.506	29	6.4
175	0.092	0.006	0.555	0.546	31	6.3	0.320	0.131	0.004	0.531	0.506	29	6.3
119	0.088	0.004	0.555	0.546	31	6.4	0.274	0.172	0.011	0.531	0.506	29	6.8
160	0.062	0.000	0.555	0.546	31	6.8	0.199	0.131	0.002	0.531	0.506	29	6.4
059	0.066	0.015	0.561	0.546	75	6.3	0.261	0.103	0.013	0.547	0.527	76	6.3
205	0.093	0.006	0.561	0.546	75	6.5	0.415	0.098	0.038	0.547	0.527	76	6.3
386	0.115	0.042	0.561	0.546	75	6.7	0.308	0.205	0.040	0.547	0.527	76	6.7
165	0.097	0.034	0.561	0.546	75	6.4	0.277	0.156	0.004	0.547	0.527	76	6.6
201	0.115	0.021	0.563	0.533	144	6.7	0.269	0.131	0.036	0.545	0.516	142	6.5
335	0.125	0.055	0.563	0.533	144	6.6	0.213	0.107	0.044	0.545	0.516	142	6.1
277	0.168	0.006	0.563	0.533	144	7.1	0.676	0.128	0.015	0.545	0.516	142	6.0
311	0.150	0.008	0.563	0.533	144	6.7	0.332	0.394	0.053	0.545	0.516	142	6.4
087	0.079	0.004	0.568	0.546	288	6.1	0.321	0.164	0.034	0.539	0.492	290	6.7
107	0.127	0.019	0.568	0.546	288	5.6	0.837	0.151	0.074	0.539	0.492	290	6.2
245	0.164	0.044	0.568	0.546	288	5.8	0.692	0.315	0.086	0.539	0.492	290	6.3
254	0.156	0.023	0.568	0.546	288	6.0	0.427	0.221	0.046	0.539	0.492	290	6.0
168	0.259	0.029	0.550	0.533	577	5.5	1.067	0.377	0.038	0.600	0.485	579	6.3
162	0.246	0.044	0.550	0.533	577	5.3	0.814	0.328	0.053	0.600	0.485	579	7.0
073	0.128	0.013	0.550	0.533	577	5.3	1.185	0.369	0.101	0.600	0.485	579	6.2
098	0.118	0.071	0.550	0.533	577	5.3	1.090	0.205	0.076	0.600	0.485	579	6.4
029	0.205	0.025	0.614	0.549	1147	6.1	1.043	0.279	0.061	0.591	0.511	1148	6.2
032	0.254	0.036	0.614	0.549	1147	5.8	0.593	0.476	0.011	0.591	0.511	1148	6.2
051	0.112	0.034	0.614	0.549	1147	6.5	0.909	0.353	0.029	0.591	0.511	1148	6.1
050	0.226	0.023	0.614	0.549	1147	6.0	1.011	0.279	0.059	0.591	0.511	1148	6.3

Table III (Cont.).

DIRECT SHEAR DATA							DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec							Constant strain rate 0.03 cm/sec						
Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -6.67C							Temperature of age hardening -6.67C						
Normal load 0.2 kg/cm <sup>2</sup>							Normal load 0.5 kg/cm <sup>2</sup>						
0.258	0.328	0.010	0.531	0.466	1	6.6	0.619	0.968	0.029	0.526	0.436	1	6.7
0.280	0.377	0.078	0.531	0.466	1	6.7	0.408	0.689	0.002	0.526	0.436	1	6.7
0.307	0.328	0.019	0.531	0.466	1	6.3	0.676	0.648	0.038	0.526	0.436	1	6.5
0.282	0.332	0.076	0.531	0.466	1	6.7	0.568	0.768	0.023	0.526	0.436	1	6.6
0.246	0.361	0.019	0.535	0.463	2	6.7	0.303	0.672	0.000	0.533	0.471	2	6.8
0.237	0.356	0.042	0.535	0.463	2	6.6	0.515	0.840	0.015	0.533	0.471	2	6.5
0.288	0.426	0.011	0.535	0.463	2	6.7	0.556	0.764	0.013	0.533	0.471	2	6.5
0.335	0.328	0.000	0.535	0.463	2	7.0	0.656	0.815	0.048	0.533	0.471	2	6.4
0.234	0.312	0.040	0.533	0.502	4	7.7	0.648	0.861	0.025	0.525	0.460	4	7.3
0.237	0.328	0.040	0.533	0.502	4	6.3	0.427	0.697	0.011	0.525	0.460	4	6.5
0.202	0.305	0.002	0.533	0.502	4	6.7	0.395	0.517	0.004	0.525	0.460	4	6.2
0.142	0.328	0.006	0.533	0.502	4	6.4	0.261	0.525	0.002	0.525	0.460	4	6.3
0.264	0.335	0.025	0.549	0.477	7	7.2	0.529	0.672	0.004	0.529	0.461	7	5.9
0.288	0.320	0.002	0.549	0.477	7	6.1	0.521	0.738	0.015	0.529	0.461	7	6.1
0.324	0.369	0.021	0.549	0.477	7	6.2	0.379	0.681	0.008	0.529	0.461	7	6.0
0.292	0.423	0.019	0.549	0.477	7	6.2	0.521	0.853	0.013	0.529	0.461	7	5.9
0.348	0.398	0.004	0.556	0.451	16	6.4	0.577	0.713	0.004	0.519	0.461	17	7.1
0.569	0.451	0.021	0.556	0.451	16	6.5	0.656	0.836	0.019	0.519	0.461	17	6.7
0.292	0.541	0.029	0.556	0.451	16	6.5	0.545	0.681	0.004	0.519	0.461	17	6.6
0.284	0.353	0.013	0.556	0.451	16	6.0	0.450	0.722	0.004	0.519	0.461	17	6.3
0.630	0.476	0.027	0.561	0.477	30	6.3	1.146	1.082	0.057	0.581	0.468	27	6.3
0.474	0.574	0.019	0.561	0.477	30	6.6	0.909	0.943	0.023	0.581	0.468	27	6.5
0.708	0.508	0.031	0.561	0.477	30	6.7	1.011	0.787	0.038	0.581	0.468	27	6.3
0.730	0.426	0.004	0.561	0.477	30	6.3	1.022	0.937	0.039	0.581	0.468	27	6.4
0.806	0.517	0.055	0.566	0.450	70	7.0	1.011	0.943	0.011	0.576	0.481	70	6.4
0.695	0.459	0.010	0.566	0.450	70	6.5	1.240	0.968	0.008	0.576	0.481	70	6.2
0.790	0.443	0.025	0.566	0.450	70	6.8	1.003	0.927	0.038	0.576	0.481	70	6.0
0.577	0.476	0.032	0.566	0.450	70	6.8	1.446	0.861	0.038	0.576	0.481	70	6.3
0.853	0.582	0.025	0.577	0.486	144	6.6	1.896	1.164	0.086	0.568	0.457	149	5.9
0.909	0.681	0.019	0.577	0.486	144	6.3	0.711	1.181	0.023	0.568	0.457	149	6.2
0.593	0.599	0.019	0.582	0.509	146	6.7	0.909	1.107	0.019	0.568	0.457	149	6.2
0.537	0.312	0.004	0.582	0.509	146	6.3	1.138	0.943	0.048	0.568	0.457	149	5.9
1.288	0.508	0.080	0.526	0.429	284	6.3	1.027	0.287	0.006	0.544	0.398	284	5.8
0.885	0.525	0.044	0.526	0.429	284	6.4	2.157	1.132	0.076	0.544	0.398	284	6.5
1.161	0.738	0.074	0.526	0.429	284	6.0	1.857	1.706	0.073	0.544	0.398	284	6.3
1.398	0.722	0.057	0.526	0.429	284	6.3	1.880	1.050	0.052	0.544	0.398	284	6.2
0.600	0.697	0.002	0.567	0.459	575	6.4	1.296	1.263	0.042	0.577	0.430	578	6.4
1.090	0.656	0.074	0.567	0.459	575	6.4	2.038	0.558	0.055	0.577	0.430	578	6.3
1.477	0.738	0.061	0.567	0.459	575	6.4	1.991	1.271	0.069	0.577	0.430	578	6.3
0.683	0.697	0.128	0.567	0.459	575	6.5	1.770	1.517	0.071	0.577	0.430	578	6.1
1.240	0.771	0.010	0.595	0.450	1144	5.8	2.204	1.173	0.069	0.581	0.420	1147	6.0
0.853	0.558	0.067	0.595	0.450	1144	6.1	1.722	1.501	0.071	0.581	0.420	1147	5.8
1.169	1.050	0.004	0.595	0.450	1144	6.0	2.094	1.337	0.069	0.581	0.420	1147	5.9
1.011	0.484	0.015	0.595	0.450	1144	5.7	1.706	1.033	0.057	0.581	0.420	1147	5.8

Table III (Cont.).

DIRECT SHEAR DATA							DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec							Constant strain rate 0.03 cm/sec						
Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)	Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -10C Normal load .01 kg/cm <sup>2</sup>							Temperature of age hardening -10C Normal load .02 kg/cm <sup>2</sup>						
040	0.021	0.002	0.606	0.600	1	10.5	0.050	0.045	0.000	0.543	0.538	1	9.5
020	0.025	0.000	0.606	0.600	1	9.5	0.093	0.045	0.011	0.543	0.538	1	9.5
036	0.041	0.000	0.606	0.600	1	9.0	0.058	0.038	0.038	0.543	0.538	1	9.1
065	0.041	0.004	0.606	0.600	1	9.3	0.077	0.066	0.019	0.543	0.538	1	9.1
065	0.043	0.004	0.597	0.589	2	9.3	0.088	0.066	0.006	0.564	0.547	2	9.4
049	0.037	0.000	0.597	0.589	2	9.2	0.070	0.039	0.004	0.564	0.547	2	9.6
033	0.025	0.000	0.597	0.589	2	9.2	0.071	0.048	0.021	0.564	0.547	2	9.5
049	0.035	0.001	0.597	0.589	2	9.2	0.074	0.055	0.013	0.564	0.547	2	9.1
051	0.043	0.000	0.583	0.576	4	9.2	0.071	0.041	0.002	0.551	0.535	4	9.5
055	0.035	0.019	0.583	0.576	4	8.6	0.088	0.049	0.000	0.551	0.535	4	9.4
063	0.031	0.000	0.583	0.576	4	9.9	0.111	0.043	0.015	0.551	0.535	4	9.7
055	0.033	0.013	0.583	0.576	4	9.4	0.091	0.033	0.000	0.551	0.535	4	9.4
036	0.037	0.000	0.600	0.592	7	9.8	0.090	0.046	0.006	0.576	0.558	7	9.7
055	0.026	0.000	0.600	0.592	7	8.7	0.055	0.041	0.000	0.576	0.558	7	9.0
076	0.030	0.011	0.600	0.592	7	9.4	0.105	0.064	0.000	0.576	0.558	7	9.6
065	0.039	0.000	0.600	0.592	7	9.6	0.058	0.033	0.010	0.576	0.558	7	8.9
071	0.037	0.000	0.546	0.537	16	9.5	0.123	0.048	0.002	0.569	0.566	16	10.5
073	0.032	0.002	0.546	0.537	16	9.5	0.063	0.053	0.002	0.569	0.566	16	9.9
104	0.058	0.002	0.546	0.537	16	9.4	0.103	0.043	0.010	0.569	0.566	16	8.8
089	0.059	0.002	0.546	0.537	16	9.1	0.074	0.065	0.015	0.569	0.566	16	9.1
085	0.030	0.004	0.565	0.555	30	9.5	0.150	0.085	0.006	0.547	0.539	29	9.5
103	0.048	0.017	0.565	0.555	30	9.2	0.179	0.112	0.002	0.547	0.539	29	9.5
086	0.062	0.029	0.565	0.555	30	9.3	0.135	0.127	0.002	0.547	0.539	29	9.0
115	0.048	0.006	0.565	0.555	30	9.5	0.117	0.069	0.004	0.547	0.539	29	9.1
067	0.043	0.004	0.562	0.555	68	9.3	0.149	0.068	0.004	0.556	0.547	72	9.2
132	0.049	0.019	0.562	0.555	68	8.9	0.179	0.072	0.015	0.556	0.547	72	10.0
163	0.072	0.006	0.562	0.555	68	9.4	0.098	0.062	0.002	0.556	0.547	72	9.5
096	0.062	0.008	0.562	0.555	68	9.3	0.167	0.105	0.006	0.556	0.547	72	9.5
278	0.076	0.029	0.569	0.563	144	9.4	0.206	0.122	0.019	0.595	0.574	144	9.5
322	0.078	0.002	0.569	0.563	144	9.8	0.188	0.098	0.013	0.595	0.574	144	9.5
191	0.093	0.004	0.569	0.563	144	9.6	0.156	0.069	0.008	0.595	0.574	144	9.4
167	0.057	0.038	0.569	0.563	144	9.5	0.164	0.107	0.004	0.595	0.574	144	9.6
308	0.098	0.019	0.568	0.559	282	9.3	0.325	0.162	0.025	0.563	0.545	282	9.3
242	0.123	0.040	0.568	0.559	282	9.4	0.324	0.113	0.023	0.563	0.545	282	9.4
261	0.139	0.004	0.568	0.559	282	9.2	0.254	0.180	0.019	0.563	0.545	282	9.2
209	0.127	0.015	0.568	0.559	282	9.5	0.140	0.090	0.013	0.563	0.545	282	9.2
284	0.103	0.019	0.580	0.567	571	9.5	0.392	0.115	0.073	0.567	0.547	571	9.8
316	0.074	0.006	0.580	0.567	571	9.8	0.246	0.243	0.002	0.567	0.547	571	9.3
242	0.125	0.004	0.580	0.567	571	9.6	0.485	0.128	0.010	0.567	0.547	571	9.4
234	0.098	0.002	0.580	0.567	571	9.4	0.243	0.130	0.023	0.567	0.547	571	9.4
514	0.087	0.045	0.576	0.568	1153	10.2	0.439	0.156	0.002	0.574	0.531	1153	9.6
553	0.161	0.013	0.576	0.568	1153	9.9	0.874	0.115	0.053	0.574	0.531	1153	9.4
619	0.279	0.019	0.576	0.568	1153	8.9	0.675	0.115	0.000	0.574	0.531	1153	9.3
597	0.128	0.019	0.576	0.568	1153	9.3	0.637	0.118	0.025	0.574	0.531	1153	9.2
877	0.303	0.080	0.571	0.553	3288	10.2	0.158	0.071	0.019			3337	9.7
292	0.287	0.057	0.571	0.553	3288	10.0	0.245	0.067	0.004			3337	9.3
664	0.213	0.021	0.571	0.553	3288	9.3	0.191	0.098	0.008			3337	9.5
455	0.189	0.044	0.571	0.553	3288	9.3	0.158	0.128	0.010			3337	9.0

Table III (Cont.).

## DIRECT SHEAR DATA

Constant strain rate 0.03 cm/sec

Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
0.079	0.080	0.017	0.561	0.549	1	9.9
0.071	0.054	0.002	0.561	0.549	1	9.2
0.075	0.096	0.004	0.561	0.549	1	9.3
0.075	0.078	0.008	0.561	0.549	1	9.5
0.089	0.073	0.010	0.558	0.543	2	9.5
0.074	0.082	0.011	0.558	0.543	2	9.2
0.123	0.078	0.004	0.558	0.543	2	9.5
0.088	0.069	0.019	0.558	0.543	2	9.1
0.083	0.053	0.004	0.569	0.555	4	9.6
0.084	0.058	0.002	0.569	0.555	4	9.6
0.087	0.066	0.002	0.569	0.555	4	9.2
0.063	0.063	0.019	0.569	0.555	4	8.9
0.109	0.078	0.004	0.546	0.539	7	9.5
0.156	0.098	0.002	0.546	0.539	7	9.1
0.115	0.075	0.002	0.546	0.539	7	9.3
0.081	0.049	0.000	0.546	0.539	7	9.2
0.211	0.100	0.004	0.541	0.525	17	9.9
0.155	0.082	0.004	0.541	0.525	17	9.5
0.204	0.131	0.002	0.541	0.525	17	9.1
0.164	0.094	0.008	0.541	0.525	17	9.4
0.179	0.078	0.036	0.573	0.552	29	9.5
0.166	0.087	0.011	0.573	0.552	29	9.0
0.180	0.066	0.002	0.573	0.552	29	9.2
0.107	0.070	0.000	0.573	0.552	29	9.5
0.237	0.139	0.004	0.547	0.534	72	9.6
0.201	0.098	0.011	0.547	0.534	72	9.4
0.150	0.090	0.004	0.547	0.534	72	8.8
0.246	0.136	0.004	0.547	0.534	72	9.5
0.337	0.231	0.006	0.542	0.502	144	10.6
0.463	0.394	0.006	0.542	0.502	144	10.0
0.649	0.213	0.061	0.542	0.502	144	9.4
0.352	0.130	0.004	0.542	0.502	144	9.1
0.251	0.177	0.011	0.576	0.557	284	9.4
0.278	0.138	0.011	0.576	0.557	284	9.4
0.337	0.253	0.004	0.576	0.557	284	9.2
0.403	0.197	0.057	0.576	0.557	284	9.1
0.435	0.200	0.027	0.557	0.531	572	9.6
0.281	0.134	0.008	0.557	0.531	572	9.8
0.453	0.197	0.002	0.557	0.531	572	9.1
0.536	0.259	0.004	0.557	0.531	572	8.9
0.972	0.443	0.080	0.571	0.496	1158	9.3
0.988	0.287	0.048	0.571	0.496	1158	9.5
0.469	0.590	0.088	0.571	0.496	1158	9.3
0.319	0.435	0.065	0.571	0.496	1158	9.5
0.561	0.246	0.057	0.567	0.506	3359	9.2
0.893	0.410	0.017	0.567	0.506	3359	9.0
0.774	0.394	0.050	0.567	0.506	3359	9.2
0.561	0.262	0.019	0.567	0.506	3359	9.4

## DIRECT SHEAR DATA

Constant strain rate 0.03 cm/sec

Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
0.300	0.410	0.010	0.545	0.468	1	9.9
0.474	0.426	0.011	0.545	0.468	1	9.5
0.395	0.476	0.029	0.545	0.468	1	9.1
0.250	0.443	0.008	0.545	0.468	1	9.4
0.221	0.336	0.002	0.556	0.489	2	9.4
0.297	0.368	0.018	0.556	0.489	2	9.4
0.408	0.476	0.038	0.556	0.489	2	9.4
0.261	0.292	0.013	0.556	0.489	2	9.3
0.348	0.361	0.006	0.563	0.475	4	9.9
0.447	0.440	0.017	0.563	0.475	4	9.2
0.330	0.348	0.010	0.563	0.475	4	9.0
0.340	0.325	0.019	0.563	0.475	4	9.3
0.311	0.328	0.019	0.533	0.495	7	9.3
0.250	0.344	0.011	0.533	0.495	7	9.3
0.240	0.426	0.025	0.533	0.495	7	9.0
0.398	0.374	0.027	0.533	0.495	7	8.9
0.316	0.353	0.000	0.564	0.473	17	9.8
0.458	0.451	0.015	0.564	0.473	17	9.6
0.435	0.353	0.002	0.564	0.473	17	9.4
0.435	0.435	0.021	0.564	0.473	17	9.7
0.403	0.287	0.002	0.567	0.505	30	9.4
0.324	0.410	0.000	0.567	0.505	30	9.0
0.482	0.394	0.006	0.567	0.505	30	10.0
0.419	0.402	0.000	0.567	0.505	30	9.4
0.656	0.410	0.052	0.533	0.470	72	9.1
1.011	0.615	0.046	0.533	0.470	72	9.1
0.608	0.377	0.055	0.533	0.470	72	9.1
1.130	0.722	0.044	0.533	0.470	72	9.0
0.205	0.410	0.000	0.561	0.496	144	9.6
0.616	0.525	0.015	0.561	0.496	144	9.5
0.474	0.623	0.010	0.561	0.496	144	9.2
0.632	0.558	0.027	0.561	0.496	144	9.2
0.695	0.500	0.023	0.570	0.480	306	9.4
0.727	0.599	0.019	0.570	0.480	306	9.8
0.885	0.648	0.011	0.570	0.480	306	9.4
0.624	0.779	0.076	0.570	0.480	306	9.2
0.735	0.492	0.019	0.563	0.501	551	10.0
0.790	0.492	0.053	0.563	0.501	551	8.9
1.051	0.475	0.111	0.563	0.501	551	9.1
0.972	0.467	0.063	0.563	0.501	551	8.7
1.138	0.492	0.057	0.579	0.501	1176	9.5
1.485	0.582	0.067	0.579	0.501	1176	9.2
1.564	0.812	0.111	0.579	0.501	1176	9.4
1.430	0.640	0.061	0.579	0.501	1176	9.3

Temperature of age hardening -10C  
Normal load 0.2 kg/cm<sup>2</sup>

Table III (Cont.).

DIRECT SHEAR DATA						
Constant strain rate 0.03 cm/sec						
Peak strength (kg/cm <sup>2</sup> )	Frictional resistance (kg/cm <sup>2</sup> )	Displacement at failure (cm)	Initial porosity	Test porosity	Aging time (hr)	Test temp. (-°C)
Temperature of age hardening -10C						
Normal load 0.5 kg/cm <sup>2</sup>						
0.439	0.902	0.017	0.578	0.475	1	9.4
0.490	0.959	0.021	0.578	0.475	1	9.0
0.577	0.951	0.023	0.578	0.475	1	9.1
0.673	1.148	0.065	0.578	0.475	1	9.8
0.474	0.894	0.029	0.550	0.469	2	9.7
0.496	0.866	0.021	0.550	0.469	2	9.2
0.487	0.689	0.010	0.550	0.469	2	9.2
0.474	0.763	0.019	0.550	0.469	2	9.4
0.585	0.968	0.011	0.527	0.466	4	10.0
0.379	0.377	0.019	0.527	0.466	4	9.0
0.498	0.836	0.011	0.527	0.466	4	8.9
0.450	0.681	0.031	0.527	0.466	4	9.3
0.540	0.859	0.019	0.569	0.478	7	9.4
0.716	0.853	0.023	0.569	0.478	7	9.4
0.782	1.132	0.031	0.569	0.478	7	9.2
0.577	1.017	0.032	0.569	0.478	7	9.0
0.411	0.751	0.015	0.554	0.490	17	9.6
0.537	0.795	0.031	0.554	0.490	17	9.1
0.735	0.882	0.006	0.554	0.490	17	9.1
0.472	0.479	0.019	0.554	0.490	17	9.5
0.553	0.558	0.021	0.557	0.477	30	10.0
0.909	0.861	0.036	0.557	0.477	30	9.4
1.240	0.968	0.053	0.557	0.477	30	9.0
0.916	0.845	0.063	0.557	0.477	30	8.7
1.003	1.099	0.040	0.574	0.460	72	9.5
1.319	1.214	0.057	0.574	0.460	72	9.4
1.185	1.189	0.034	0.574	0.460	72	9.1
1.161	1.271	0.019	0.574	0.460	72	9.0
1.613	1.099	0.031	0.569	0.466	144	9.8
1.564	1.304	0.038	0.569	0.466	144	9.4
1.398	1.435	0.040	0.569	0.466	144	9.5
1.714	1.132	0.080	0.569	0.466	144	9.3
1.169	1.107	0.038	0.590	0.435	306	9.2
1.059	1.312	0.153	0.569	0.435	306	9.3
1.209	1.542	0.002	0.569	0.435	306	9.1
1.446	1.271	0.057	0.569	0.435	306	9.0
1.541	1.369	0.021	0.550	0.444	575	9.5
2.252	1.845	0.096	0.550	0.444	575	9.1
1.793	1.804	0.053	0.550	0.444	575	9.0
1.462	1.615	0.057	0.550	0.444	575	8.6
1.588	1.435	0.036	0.582	0.458	1182	10.1
1.296	1.697	0.055	0.582	0.458	1182	10.1
1.146	1.517	0.038	0.582	0.458	1182	9.8
1.683	1.681	0.055	0.582	0.458	1182	9.6
0.514	0.623	0.019	0.578	0.418	3069	8.5
0.553	0.590	0.044	0.578	0.418	3069	9.4
0.619	0.649	0.057	0.578	0.418	3069	8.5
0.597	0.558	0.011	0.578	0.418	3069	8.9