Cements in Canada

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TECHNICAL NOTE

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SUBJECT Cements in Canada

An enquiry has been received by the Division of Building Research, National Research Council, from a European cement manufacturing company with reference to the quantity and types of cements produced and used in Canada. The following information has been assembled from available data.

I. Types of cements

The Canadian Standards Association (CSA) specifications for portland cement includes 3 types of portland cement:

1) Normal portland cement
2) High-Early-Strength portland cement; and
3) Sulphate Resistant portland cement.

These cements correspond in their chemical and mineralogical composition to Types I, III and V respectively of ASTM specifications, but Canadian cements are generally less finely ground than American cements.

The small quantities of air-entraining portland cement is made by grinding normal portland cement clinker with an air-entraining agent.

The masonry cement, according to the recently proposed CSA specifications, is similar to Type II high strength ASTM masonry cement. It is manufactured by simultaneous grinding of normal portland cement clinker and limestone (up to 50%).

The oil-well cements are not, so far as is known, manufactured in Canada. The Canadian requirements for this type of cement are covered by imports.

II. Consumption and production

The consumption of portland cement in most provinces is largely covered by local plants. Exceptions are special types of cement such as oil-well cements, sulphate resistant cement, masonry cements, etc., imported from U.S.A. or other countries.

The producers of portland cement, the location of their plants and the brands of cement produced are as follows:

1. British Columbia Cement Co. Ltd., 500 Fort St., Victoria, B.C. Branch factory at Bamberton, Tod Inlet P.O.V.I., B.C. Brands: "Monocrete", "Elk", "Ferrocrete".

2. Canada Cement Co. Ltd., Canada Cement Co. Bldg., Montreal, P.Q. Factories at Havelock, N.B.; Montreal and Hull, Que.; Belleville and Port Colborne, Ont.; Exshaw, Alta.; Fort Whyte, Man.; Distributing plants are in Halifax, N.S., Chatham, N.B., Quebec, Que., Toronto and Windsor, Ont. Brands: "Canada", "Kalicrete".

3. North Star Cement Co., P.O. Box 436, Corner Brook, Nfld. Portland Cement brand: "North Star".

4. St. Lawrence Cement Co., Villeneuve, Que.

5. St. Mary's Cement Co. Ltd., 357 Bay St., Toronto 1, Ont. Mill at St. Mary's, Ont.

6. Ciment Québec in St. Basile de Portneuf, P.Q.

All these plants manufacture the normal type of portland cement. In addition the Fort Whyte plant produces some Kalicrete or some sulphate resistant portland cement; the Montreal plant manufactures also high early strength portland cement. Masonry cement is produced at the Belleville plant.

According to data obtained from the Federal Bureau of Statistics, Canadian consumption, production, import and export of portland cement during the last 4½ years was as follows (in barrels-shipment) (1 barrel = 350 lb.; 1 lb. = 453 gm.):

Production per Province:

	Quebec	Ontario	Manitoba	Alberta	B.C.	N.B. & Nfld.
1951	7,055,164	5,438,101	1,539,612	1,649,909	1,325,026	-
	16,633,377	12,494,677	4,108,752	3,898,043	3,311,436	-
1953	7,400,912	7,076,181	1,614,301	3,098,664	1,826,543	1,219,734

Construction of 3 cement plants in Newfoundland, New Brunswick and Quebec increased by 8% the output of the portland cement in comparison to the 1951 value.

Year	Total Production	Import	Export	Consumption
1950	16,741,826	1,386,219	23,909	18,104,136
1951	17,007,812	2,327,431	2,590	19,332,653
1952	18,351,964	2,913,981	4,305	21,260,640
1953	22,238,335	8,690,000 in		
½ 1954	10,568,303	hundred weight		

Import in 1953 in hundred weight

U.K.	2,500,000
Belgium	868,000
Denmark	48,000
Germany	948,000
Alaska	284,000
U.S.A.	4,331,000

Official data on Canadian consumption of different types of cement are not available.

The Type IV A.S.T.M. cement is not manufactured and not used in Canada, and the normal portland cement is used in the construction of dams.

III. Chemical composition

The chemical composition of Canadian cements does not differ much from that of the corresponding types, manufactured in U.S.A.

1. Canadian Normal Portland Cements

Constituents	% by weight			
SiO_2	20.7	21.3	22.05	21.4
Al_2O_3	6.1	5.3	4.95	6.4
Fe_2O_3	2.8	2.9	2.67	2.9
CaO	63.1	63.1	63.15	63.2
MgO	2.3	3.2	3.68	2.2
SO_3	2.7	1.9	2.80	2.0
Loss in ignition	1.1	1.4	1.85	0.63
Na_2O	0.47	0.09	0.13	0.60
K_2O	0.81	0.54	0.48	0.90
Insoluble in acid	0.19	0.38	-	0.18

Constituents (cont'd)	% by weight			
Free lime	0.96	1.3	-	0.78
Alkalinity as Na_2O	1.00	0.45	-	-
200-mesh % passing	91.0	88.2	-	92.5
325-mesh % passing	85.3	81.8	-	-
Wagner SSA (cm^2/gm)	-	1540	-	1395
Blaine SSA (cm^2/gm)	2749 -	-	-	2723

2. Sulphate resisting portland cements

Summary of the analyses of sulphate resistant portland cements which have the highest resistance to the action of sodium and magnesium sulphate are represented in the following Table. Analysis is by the U.S. National Bureau of Standards.

TABLE I

Analyses	Ten cements first in resistance		
	Minimum	Maximum	Average
	Per cent	Per cent	Per cent
Loss on ignition	1.1	2.2	1.4
Silica (SiO_2)	20.2	23.6	22.5
Ferric oxide (Fe_2O_3)	2.8	5.2	3.6
Ferrous oxide (FeO)	0.00	0.30	0.04
Titanium oxide (TiO_2)	0.08	0.26	0.22
Phosphoric anhydride (P_2O_5)	0.03	0.63	0.12
Manganese (calc. as Mn_2O_3)	0.01	0.47	0.11
Alumina (Al_2O_3)	2.8	4.9	4.0
Calcium oxide (CaO)	62.1	65.9	64.0
Magnesia (MgO)	1.1	3.6	2.1
Sodium oxide (Na_2O)	0.15	0.67	0.28
Potassium oxide (K_2O)	0.11	0.51	0.36
Sulphuric anhydride (SO_3)	1.4	1.9	1.7
Insoluble residue	0.05	0.28	0.15
Free lime (CaO)	0.1	1.4	0.8
Ratio Fe_2O_3 to Al_2O_3	0.53	1.86	0.94
Ratio Al_2O_3 to Fe_2O_3	1.00	1.90	1.17
Per cent retained on No. 200	3.5	12.5	5.9
Per cent retained on No. 325	8.0	30.0	15.7
Surface area (Sq. cm. per gm.)	1160	1820	1570

Table I continued on page 5.

Analyses (cont'd)	Ten cements first in resistance		
	Minimum	Maximum	Average
	Per cent	Per cent	Per cent
Calculated compounds:			
$3CaO.Al_2O_3$	2.7	6.7	4.6
$3CaO.SiO_2$	36.4	62.2	49.3
$2CaO.SiO_2$	11.7	39.1	27.4
$4CaO.Al_2O_3.Fe_2O_3$	6.1	14.6	10.5
Sum of $3CaO.Al_2O_3$ and $4CaO.Al_2O_3.Fe_2O_3$	8.8	21.3	15.1

3. Masonry cements

Composition and methods of manufacturing of masonry cement are in accordance with methods and apparatus described in Appendix B of the recently proposed CSA Specification.

Time of setting, Gilmor:	Initial, not less than	- 60 min.
	Final, not more than	- 12 hrs.
Strength, compressive :	7 days, min.	- 500 psi
	28 days, min.	- 900 psi

Soundness, Autoclave expansion, 48 hrs. max.	- 1%
Water retention, Flow, min.	- 70%
Air content, volume, min.	- 12%
Adsorption, weight, increase, max.	- 5.0%
Staining test, soluble alkali as Na_2O, max.	- 0.03%

Example:	
SiO_2	- 12.80%
Al_2O_3	- 4.58%
Fe_2O_3	- 1.72%
CaO	- 55.76%
MgO	- 2.20%
SO_3	- 1.50%
Loss on ignition	- 20.55%
Total	- 99.11%

Fineness: 325 - mesh	- 96.0% passing
Blaine	- 6300 cm^2/gm
Water retention	- 87.0%
Initial set	- 4 hrs. 45 min.
Autoclave expansion	- 0.07%
Specific gravity	- 2.90

4. High early strength portland cement

Example of chemical composition of the high early strength portland cement is as follows:

SiO_2	- 21.3% by weight	C_4AF	- 8.0%
Al_2O_3	- 5.8% " "	C_3A	- 10.5%
Fe_2O_3	- 2.8% " "	C_3S	- 50.9%
CaO	- 62.69% " "	C_2S	- 18.3%
Free lime	- 0.79% " "	$CaSO_4$	- 5.7%
Combined lime	- 61.09% " "	Initial set	- 1 min. 46 secs.
MgO	- 2.7% " "	Final set	- 3 hrs. 35 min.
SO_3	- 3.3% " "	200 mesh	- 99.7% passing
K_2O	- 0.61% " "	325 mesh	- 98.0% "
Na_2O	- 0.38% " "	SS Wagner	- 2639 cm^2/gm
Loss ignition	- 1.2% " "	SS Blaine	- 5048 cm^2/gm
Insoluble	- 0.45% " "		

5. Oil-well cements

American Petroleum Institute (API) Std 10A Specifications for oil-well cements (tentative) first edition March 1953, mentions 6 different types of oil-well cements:

Class A - for use to 6000 ft. depth - similar to Type I - cement ASTM.
Class B - for use to 6000 ft. depth, when sulphate resistance required, similar to Type II cement ASTM.
Class C - for use to 6000 ft. depth, when high early strength is required; similar to Type III cement ASTM.
Class D - for use to 12,000 ft. depth, when moderately high temperatures and high pressures are encountered.
Class E - for use to 14,000 ft. depth, when high temperatures and high pressures are encountered.
Class F - for use to 16,000 ft. depth, when extremely high temperatures and pressures are encountered.

Specifications for the thickening times (pumpability times) of these cements are given in the API-RP-10B Specifications. Requirements for thickening times of Classes D, E and F cements, in either the Halliburton or Standard of California testers are now under study by the subcommittee on Thickening Time Values of the API Committee on Standardization of Oil-Well Cements.

In a co-operative series of thickening-time tests sponsored by the above-mentioned API Sub-committee, 12 laboratories made 755 tests on 12 API Class D and E (slow-set) oil-well cements. At the time these cements were chosen, they represented all of the slow-set oil-well cements manufactured in the United States. No one in U.S.A. is offering a Class F cement.

At the Denver meeting of the sub-committee the following recommendations were agreed upon:

1: Thickening-Time Values

Class D Cement: Minimum thickening-time values for the atmospheric pressure testers were recommended as follows:

80 - 140°F Standard of California Tester - 3 hr.
80 - 140°F Halliburton Tester - 3 hr. 15 min.

Class E Cement: It was decided that specifications for these cements should be based solely on results obtained with the Stanolind tester.

2: Slurry Viscosities:

Class D and E Cements: The viscosity of a slurry made from these cements should not exceed the following maximum values during the period of 15 to 30 min. after the start of the thickening-time tests:

Standard of California Tester - 8 oz. pull (at slow speed)
Halliburton Tester - 25 poises
Stanolind Tester - 30 poises

The study on the reproducibility of the seven different methods showed that the probable error and average deviation lie within the narrow range of 2.6 to 5.5% and 3.1 to 6.5%, respectively, of the average thickening-time values. This indicates good reproducibility for this type of test. All three testers will give essentially the same reproducibility in tests, if a few precautions as recommended in the report are taken.

Composition of Cements:

	Class D		Class E	
Analysis %	1	2	1	2
SiO_2	21.60	24.44	22.48	21.1
Al_2O_3	24.32	2.79	4.61	5.2
Fe_2O_3	3.82	3.01	4.45	4.6
CaO	61.68	65.76	64.20	64.4
MgO	4.69	0.75	1.18	1.00
SO_3	1.84	1.84	1.69	2.10
Loss on ignition	1.20	1.07	0.84	0.77
K_2O	0.27	0.16	0.35	0.61
Na_2O	0.46	0.07	0.18	0.15
Total as Na_2O	0.64	0.18	0.41	0.55
C_3S	47.0	53.48	48.23	54.1
C_2S	26.5	29.80	28.14	19.7
C_3A	5.0	2.28	4.66	6.0
C_4AF	11.6	[illegible].15	13.53	14.0
$CaSO_4$	3.1	3.13	2.87	3.6
SS Wagner (cm^2/gm)	1559	1382	1520	1205
Retarded or not	Ret.	Ret.	Ret.	Ret.

Among the special oil-well cements the following types may be mentioned:

1. Gel Cement - Blend of either ASTM Type I or slow-set cement with approximately 2 to 15% bentonite. The use of bentonite permits the use of more water in the slurries and results in slurries having lower densities, lower strengths, and lower unit costs. The chief advantages of it, are:

    1. Bentonite tends to keep the cement particles in suspension and, as a result, prevents formation of water pockets in the water column after it has been placed.

    2. Lower-density slurries give lower hydrostatic pressures on surrounding formation.

    3. Lower strength gives better penetrability and less shattering during perforation.

    Disadvantages of using bentonite in cements, especially in larger quantities, appear to be:

    1. Shortening the thickening time of both the ASTM Standard I and slow-set cements.

    2. Higher W/C ratio lowers the resistance to sulphate attack and increases the permeability to water of the hardened product.

2. Modified Gel Cements - Blend of ASTM Type I cement with approximately 8.0 to 12.0% bentonite and about 0.10 to 0.50% calcium ligno-sulphonate.

3. Pozzolane Cement - Blend of ASTM Type I or slow-set cement with approximately equal volumes of fly ash or volcanic ash.

4. Low Water-loss Cement - ASTM Type I or slow-set cement containing low water-loss additives (polyvinyl alcohol, methyl cellulose, inulin, salts of alkyl sulphoethyl cellulose ethers, and other organic additives).

5. Retarded Slow-set Cements - Composition similar to ASTM Type II, containing retarding additives, which are organic materials: casein or other proteins; modified starches and dextrins, natural gums; hydroxy organic acids and their salts; salts of lignin sulphonic acid; sugars; cellulose ethers and esters; oxidized cellulose; boric acid and its salts; oxyaldehydes; oxykeltones and alkali phosphates.

6. Unretarded Slow-set - Calculated C_3A is zero. Sufficient Fe_2O_3 used in composition to give a calculated C_2F of 0 to about 5.0%.

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