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PHYSICAL AND CHEMICAL PROPERTIES AND DURABILITY OF SOME WHITE AND NORMAL PORTLAND CEMENTS

by

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MINERAL PROCESSING DIVISION

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V.M. Malhotra*

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SUMMARY OF RESULTS

This investigation was carried out at the request of Schokbeton Quebec Inc., St. Eustache, P.Q., to determine the physical and chemical properties and durability of five white and two normal portland cements.

Whiteness of the samples, measured by the light-reflectance values, varied from 79.4 per cent for German Dyckerhoff to 88.7 per cent for Japanese Onoda white cement.

The flow of the cement mortars, measured by flow table tests, varied from 111 per cent for the German Dyckerhoff to 125 per cent for the Japanese Onoda white cement.

The 14-day compressive strength of 2-inch mortar cubes made with white cements varied from a low of 3590 psi for Belgian CBR to a high of 4975 psi for Japanese Onoda.

Freeze-thaw test results showed that Belgian CBR and Japanese Onoda cements have superior durability compared to other white and normal portland cements; the test cubes made with these two samples were in excellent condition at the completion of 500 freeze-thaw cycles whereas all the other specimens had deteriorated at less than 200 freeze-thaw cycles.

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CONTENTS

	Page
Summary of Results	i
Introduction	1
Scope of Investigation	1
Types of Cements Under Investigation	2
Normal Portland Cements	2
White Portland Cements	2
Physical and Chemical Tests	2
Physical Tests	2
Fineness Determination	3
Whiteness Evaluation	3
Chemical Tests	3
Strength and Durability of Cements	6
Test Mixes	6
Test Specimens	7
Test Results	7
Discussion of Results	10
Conclusions	11
References	11

(Continued)

CONTENTS (Concluded)

LIST OF TABLES

No.		Page
1.	Determination of Fineness of Cements	4
2.	Cement Whiteness or Reflectance Values	4
3.	Chemical Analyses of Cements	5
4.	Grading of Ottawa (Illinois) Silica Sand	6
5.	Flow of Standard Mortar Mixes	7
6.	Density and Compressive Strength of Standard Mortar Cubes	8
7.	Summary of Freeze-Thaw Test Results	9

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INTRODUCTION

This investigation was undertaken at the request of Schokbeton Quebec Inc., St. Eustache, P.Q. Ten-pound samples of six different cements were submitted by the above company on November 21, 1963. This company is producing precast architectural and structural concrete elements for markets in Quebec and Ontario. The company is concerned about the durability of its products and is interested in determining the relative durability of exposed concrete structural units made with different white and normal portland cements. Preliminary cement durability studies were reported in Mines Branch Test Report MPT 63-48 (1).

SCOPE OF INVESTIGATION

This investigation was carried out to determine the physical and chemical properties and durability of some white and normal portland cements.

The physical tests consisted of determining the fineness and reflectance values of the various cements, using the Alpine Air-Jet Sieve and Hunter Colour Difference Meter.

The chemical analyses were carried out using standard laboratory techniques.

The durability of the cements was determined by subjecting 2-in. standard mortar cubes to repeated cycles of freezing and thawing in an automatic unit.

TYPES OF CEMENTS UNDER INVESTIGATION

Samples of two Canadian normal portland cements and four imported white portland cements were submitted for investigation.

Normal Portland Cements

1. Ciment Quebec, manufactured by Ciment Quebec, Inc., St. Basile, Cte Portneuf, P.Q.

2. St. Lawrence Cement, manufactured by St. Lawrence Cement Co., Clarkson, Ontario.

White Portland Cements

1. German Dyckerhoff, manufactured by Dyckerhoff Zementwerne A.G., Wiesbaden, West Germany.

2. Danish Lion, manufactured by Aalborg Portland Cement Fabrik, Aalborg, Denmark.

3. Belgian CBR, manufactured by Cimenteries et Briqueteries Reumés, Bruxelles, Belgique.

4. Japanese Onoda, manufactured by Onoda Cement Co. Ltd., Marunouchi, Tokyo, Japan.

In addition, a Canadian white cement was bought locally and included in this investigation. It is understood that, to manufacture this cement, clinker is imported and ground in Canada.

PHYSICAL AND CHEMICAL TESTS

Physical Tests

These consisted of determining the fineness, whiteness and reflectance of the various cements.

Fineness Determination

Fineness of the samples was determined by the percentage retained on a ASTM No. 200 sieve. The Alpine Air-Jet Sieve (2) was used instead of the CSA standard hand sieving method*. The principle of the Alpine Air-Jet Sieve consists in the use of an air current to disperse the material on the sieve and to carry the finer fractions through it. This machine works without any mechanical movement of the screen cloth or other part in contact with the material.

The fineness test results are shown in Table 1. Also included in this table are the calculated equivalent values for the CSA standard method for determining fineness.

Whiteness Evaluation

The Hunter Photoelectric Colour Difference meter** was used to evaluate the whiteness and reflectance values of the cements. The test results are shown in Table 2.

Chemical Tests

The chemical analyses of both the normal and white portland cements are given in Table 3. Also included in this table are ranges of chemical composition for typical white cements from the United States (3). It will be noted that the Fe_2O_3 and MgO content of the white cements is considerably lower than that of the normal portland cements.

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*CSA Standard A5-1961, Section 7.2.1.

**Hunter Lab. D25 Colour Difference Meter: Available from Hunter Associates Laboratory Inc., 5421 Brier Ridge Road, McLean, Virginia, U.S.A.

TABLE 1

Determination of Fineness of Cements

Type of Cement	Percentage Retained on No. 200 Sieve	
	Alpine Air-Jet Sieve Method	Equivalent CSA Standard Method*
Normal Portland Cements		
Ciment Quebec	9.0	11.5
St. Lawrence	6.5	8.2
White Portland Cements		
Canadian White	1.2	1.5
German Dyckerhoff	2.7	3.4
Danish Lion	1.8	2.3
Belgian CBR	1.8	2.3
Japanese Onoda	1.0	1.3

*To obtain equivalent percentage retained on No. 200 sieve by hand sieving, multiply the values obtained by the Alpine Air-Jet Sieve by 1.27. From Reference (2).

TABLE 2

Cement Whiteness or Reflectance Values*

Type of Cement	Value by Hunter Colour Meter L (number)	Reflectance Values G,** (per cent)
Normal Portland Cements		
Ciment Quebec	56.3	31.7
St. Lawrence Cement	54.1	29.3
White Portland Cements		
Canadian White	91.5	83.7
German Dyckerhoff	89.1	79.4
Danish Lion	92.7	85.9
Belgian CBR	90.7	82.3
Japanese Onoda	94.2	88.7

*From Mines Branch Test Report MPT 64-5.

**$G = \frac{L^2}{10,000} \times 100.$

TABLE 3

Chemical Analyses of Cements*

Type of Cement	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	SO_3 %	L.O.I. %	Insoluble Residue %
Normal Portland Cements								
Ciment Quebec	20.85	5.59	1.93	64.12	2.47	3.07	1.13	0.30
St. Lawrence	21.16	5.35	2.07	63.04	3.07	2.52	2.20	0.70
White Portland Cements								
Canadian White	23.20	4.47	0.19	66.88	2.69	2.08	1.03	0.52
German Dyckerhoff	21.98	4.91	0.41	65.40	0.95	2.88	3.68	0.29
Danish Lion	24.10	3.75	0.41	68.20	0.72	1.77	1.18	0.86
Belgian CBR	21.84	5.60	0.34	67.60	0.52	2.53	1.42	0.70
Japanese Onoda	23.40	4.16	0.20	65.12	1.72	2.41	3.37	0.16
Typical U.S.A. White Cements**	21.54 to 23.75	4.10 to 6.90	0.70 to 0.80	64.16 to 64.50	1.58 to 2.65	1.79 to 2.22	2.26 to 2.96	-

*From Mines Branch Internal Report MS-AC-64-268.

**From Reference (3).

STRENGTH AND DURABILITY OF CEMENTS

The strength and durability of the various cements were determined using standard 2-inch mortar cubes. The details of mortar mixes, test specimens, and test results are described below.

Test Mixes

A standard mortar mix, 1 part cement to 2.75 parts graded standard Ottawa (Illinois) silica sand, by weight, was made for each of the 7 cements. The water content of the mixes was kept constant (13.6 per cent of dry weight) and the resulting mortar flow* was measured. The grading of the sand is given in Table 4. The proportions of mortar mixes and the resulting flow, in per cent, for the different cements are given in Table 5.

TABLE 4

Grading of Ottawa (Illinois) Silica Sand

ASTM Sieve Size	Per cent Passing
No. 30	99.6
No. 50	24.6
No. 100	1.4

*CSA Standard A5-1961, Section 7.8.9.

TABLE 5

Flow of Standard Mortar Mixes*

Type of Cement	Flow, Per cent
Normal Portland Cements	
Ciment Quebec	105
St. Lawrence	115
White Portland Cements	
Canada White	125
German Dyckerhoff	111
Danish Lion	116
Belgian CBR	117
Japanese Onoda	122

*Proportion of a typical mix: cement = 500 g; sand = 1375 g; water = 255 ml.

Test Specimens

Six 2-inch cubes were moulded from each mortar mix. The casting and curing methods followed were those outlined in sections 7.8.10 and 7.8.11 of CSA Standard A5-1961.

Test Results

The test cubes were removed from the moist curing room at the age of 14 days and their saturated, surface-dry densities were determined. These are given in Table 6. Two of the cubes were then tested in compression in a 60,000.lb Tinius Olsen testing machine and the test results are also included in Table 6.

Two of the remaining four cubes from each mix were subjected to repeated cycles of freezing and thawing according to ASTM Test Method C291-61T*. The automatic freeze-thaw unit performs approximately

*Tentative Test for Resistance of Concrete Specimens to Rapid Freezing in Air and Thawing in Water (C291-61T), 1961, Book of ASTM Standards, Part 4, p. 756.

8 cycles per day; one complete cycle from 40 ± 3°F to 0 ± 3°F and back to 40 ± 3°F requires 2 hours and 51 minutes.

The remaining two cubes from each mix were designated "reference cubes" and were transferred back into the moist curing room.

The test cubes subjected to repeated cycles of freezing and thawing were examined visually at various intervals. When they had deteriorated noticeably they were removed from the freeze-thaw unit and were tested in compression, along with the corresponding reference cubes. The test results are shown in Table 7. Also shown in this Table is the residual strength, which is the ratio of the compressive strength of the freeze-thaw cubes to that of the standard-cured cubes, expressed as a percentage.

TABLE 6

Density and Compressive Strength of Standard Mortar Cubes

Type of Cement	Properties of Test Cubes at 14 Days	
	Density*, lb/cu ft	Compressive Strength**, psi
Normal Portland Cements		
Ciment Quebec	135.20	3700
St. Lawrence	134.97	3625
White Portland Cements		
Canadian White	138.23	4475
German Dyckerhoff	134.43	3975
Danish Lion	138.09	4175
Belgian CBR	130.74	3590
Japanese Onoda	134.41	4975

*Mean of six 2 x 2 in. cubes.

**Mean of two 2 x 2 in. cubes.

TABLE 7

Summary of Freeze-Thaw Test Results

Type of Cement	Freeze-Thaw Mortar Test Cubes		Compressive Strength of Standard-Cured Reference Cubes, psi (mean of two results)	Residual Strength of Freeze-Thaw Test Cubes, %	Remarks
	Number of Freeze-Thaw Cycles at which Noticeable Deterioration Occurred	Compressive Strength, psi (mean of two results)			
Normal Portland Cements					
Ciment Quebec	86	3135	4160	75.4	Pronounced scaling of all faces.
St. Lawrence	99	1750	4260	41.1	Both cubes deteriorated.
White Portland Cements					
Canadian White	148	1225	5300	23.1	Both cubes badly deteriorated.
German Dyckerhoff	166	2100	5010	41.9	Both cubes badly deteriorated.
Danish Lion	175	1675	5210	32.2	Edges of both cubes badly damaged.
Belgian CBR	500	4150	4400	94.4	Both cubes in excellent condition.
Japanese Onoda	500	5475	6350	86.4	Both cubes in excellent condition.

DISCUSSION OF RESULTS

The physical test results showed that the white cements were finer than the normal portland cements. The equivalent percentage retained on a No. 200 sieve varied from 1.3 per cent for the Japanese Onoda to 3.4 per cent for the German Dyckerhoff, whereas the corresponding values for the normal portland cements were 11.5 and 8.2 per cent for Ciment Quebec and St. Lawrence cements.

Reflectance, G, which is a measure of relative whiteness of cements, varied from 79.4 per cent for the German Dyckerhoff to 88.7 per cent for the Japanese Onoda cement, which appears to be the whitest of all the cements tested. The normal portland cements, which are grey, had reflectance values of about 30 per cent.

Both the Fe_2O_3 and MgO contents of the white cements were considerably lower than those of the normal portland cements. Further, the chemical analyses of these white cements show that their chemical composition falls generally within the range of the values for typical U.S.A. white cements.

For the same water content, the white cements had higher mortar flows than the normal cements. Among the white cements, the Japanese Onoda and the Canadian White had mortar flow values of 122 and 125 per cent. The flow values of the other white cements varied from 111 to 117 per cent. This indicates that the Japanese Onoda and the Canadian White cements required less water for the same workability than other white and normal portland cements.

The 14-day compressive strength of the 2-inch mortar cubes made with different cements varied widely. These ranged from a low of 3590 psi for the Belgian CBR cement to a high of 4975 psi for the Japanese Onoda. The corresponding strengths of the 2-inch cubes made with the normal portland cements were about 3650 psi. Except for the Belgian CBR white cement, the compressive strengths of the white cement were higher than those of the normal portland cements.

The freeze-thaw test results show that the Belgian CBR and the Japanese Onoda have excellent durability. The test specimens made using these cements were in good condition at the completion of 500 freeze-thaw cycles; the residual compressive strengths were high, 94.4 and 86.4 per cent respectively. The test specimens made with the Canadian White, German Dyckerhoff and Danish Lion showed noticeable deterioration at less than 200 cycles and the residual compressive strengths were low.

The test cubes made using normal portland cements showed poor resistance to repeated cycles of freezing and thawing. The specimens deteriorated in less than 100 freeze-thaw cycles and had low residual compressive strengths.

CONCLUSIONS

From the results of this investigation it is concluded that:

1. Of all the white cements tested, the Japanese Onoda cement appears to be finer, whiter and of higher compressive strength.

2. The white cements showed better durability than the normal portland cements. Among the white cements, the test specimen made using the Japanese Onoda and the Belgian CBR cements performed best in the freeze-thaw tests; these specimens were in excellent condition at the completion of 500 cycles of freezing and thawing.

3. The Japanese Onoda and the Canadian White cements had lower water requirements for the same workability than the other white and normal portland cements.

REFERENCES

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