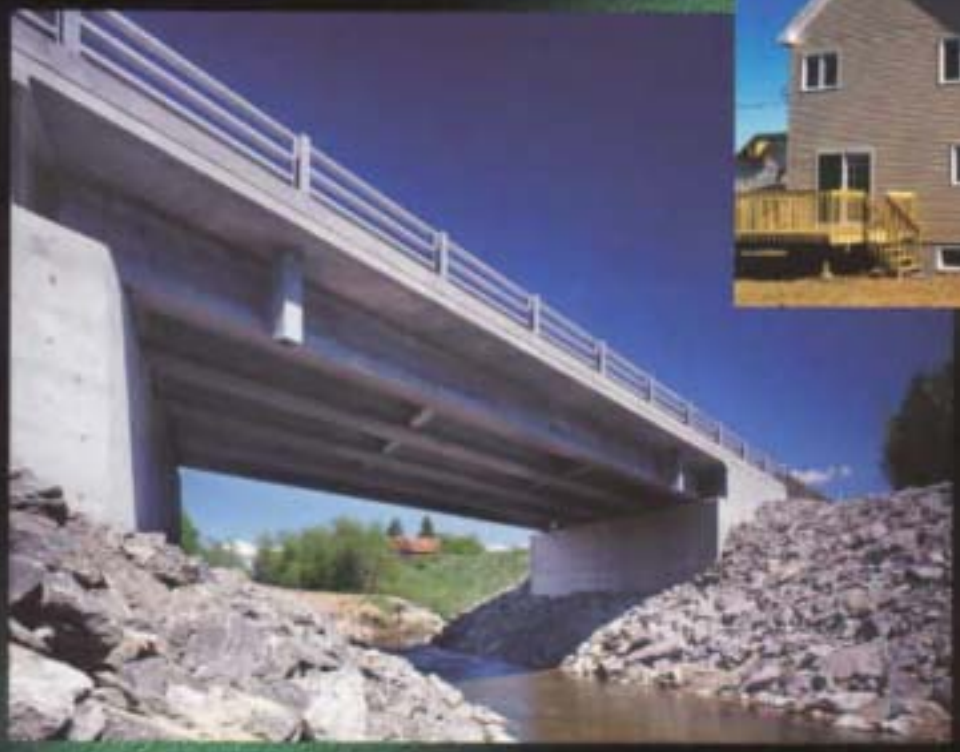
ANNEX A

Publicity Brochure and Technical Bulletin for Tercem 3000™

BLENDED HYDRAULIC LAFARGE CEMENT

TERCEM 3000™

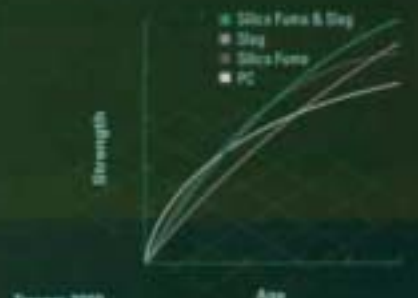


Higher Ultimate Strength
Reduction in Permeability
Improved Rheology
Better Finishability

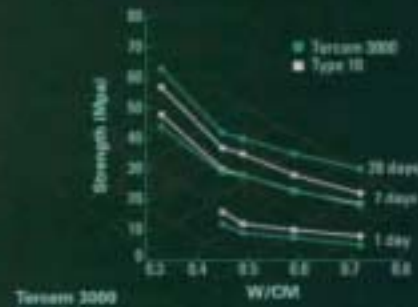
LAFARGE
NORTH AMERICA

TERCEM 3000™

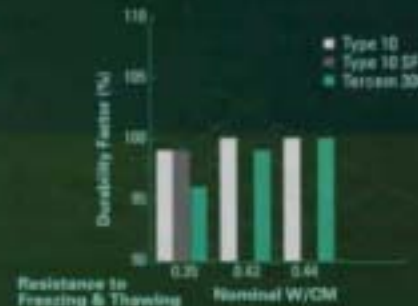
Performance Benefits For The Concrete Industry



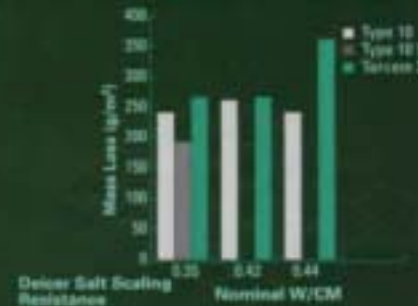
Tercem 3000



Tercem 3000



Resistance to Freezing & Thawing



Deicer Salt Scaling Resistance

Lafarge Tercem 3000, a new Ternary Composite Cement, is the ideal product when concrete requires additional strength and durability. Concrete containing this product has superior placing and finishing qualities. The precise combination of supplementary cementing materials in this portland based product results in a cement suitable for a wide variety of applications.

Tercem 3000 can be used in vertical applications and in flatwork. The improved workability with this product makes it ideal for walls, beams, columns and precast products. The product is also well adapted for use in foundations, bridges, columns,etc. In applications such as roads, sidewalks, driveways, curbs and gutters, and industrial, commercial, and institutional floors, this product provides the desired finishing characteristics in the plastic concrete, and is ideally suited for situations during warm weather. The use of Tercem 3000 gives outstanding results in roller compacted concrete. The reduced permeability in the hardened concrete results in improved durability.

Lafarge Tercem 3000 meets the applicable requirements of Canadian Standards Association (CSA) A-3000 Cementitious Materials Compendium A362 Blended Hydraulic Cement and ASTM C 1157 Standard Performance Specification for Hydraulic Cement.

This product can be used to produce quality concrete meeting design requirements for strength and durability.

Some of the criteria for high quality concrete include the selection of suitable aggregates, a proper mix designed to meet the expected exposure conditions for the structure, quality controlled concrete production, and proper placing, curing, and protection methods.

All of the requirements of the particular project specifications, CSA A 23.1, as well as the recommendations in "Design and Control of Concrete Mixtures" published by the Cement Association of Canada should be followed.

Advantages

- Improved compressive strength.
- Lower permeability.
- Improved rheology and pumpability of concrete.
- Reduced concrete bleeding.
- Improved finishability.

Specifications

1. Tercem 3000 meets the following specifications: CSA A 362 - Types 10E, 20E (moderate sulphate), 50E ASTM C 1157M - Types GU, HE, MS, HS
2. The water demand for Tercem 3000 is equivalent to Type 10 cement
3. The strength of concrete produced with Tercem 3000 is:
   - lower at 1 day
   - equivalent at 7 days
   - higher at 28 days

   compared to similar concrete produced with Type 10 cement
4. The use of Tercem 3000 significantly reduces chloride permeability compared with Type 10 cement.
5. Coulomb values at 28 days are slightly higher than those determined for similar concrete produced with Type 10E-SF cement, but are generally comparable after 56 days.
6. The expansion of concrete containing highly-reactive aggregate is reduced significantly when Tercem 3000 is used. The 2-year expansion is lower than the 0.04% maximum commonly used in specifications.
7. Excellent durability to freeze-thaw cycling was observed for air-entrained concrete produced with Tercem 3000, over a wide range of water-cementing materials ratios (W/CM).
8. Salt scaling resistance of concrete produced with Tercem3000 meets the requirements provided that W/CM < 0.45.
9. Tercem 3000 meets ASTM and CSA limits for sulphate resistant cement (Type 50E).

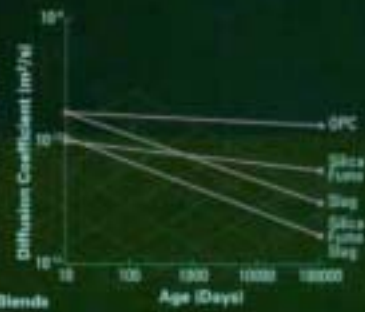
Chloride Permeability

Chloride Permeability

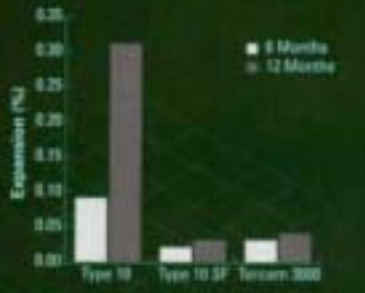
Benefits

Improvement of 28 day strengths in the order of 10% to 20% over a wide range of mix designs and W/C ratios

- ASR reduction
- Durability
- Easier finishing
- Hot weather performance
- Natural retarder
- Reduce bleeding
- Easy to pump
- Reduced segregation
- Only 1 silo required



Ternary Blends



Sulphate Resistance

LAFARGE

TERCEM 3000 Blended Hydraulic Cement

Lafarge Canada Inc. is part of the Lafarge group, one of the world's foremost producers of building materials. The group holds leading positions in each of its core businesses: Cement, Aggregates and Concrete, Roofing and Gypsum. Lafarge is committed to the advancement of the construction industry by bringing greater safety, comfort, and beauty to our everyday lives.

www.lafargenorthamerica.com

LAFARGE
NORTH AMERICA

Distributed by Lafarge Canada Inc.

For more information, please contact your local Lafarge representative.

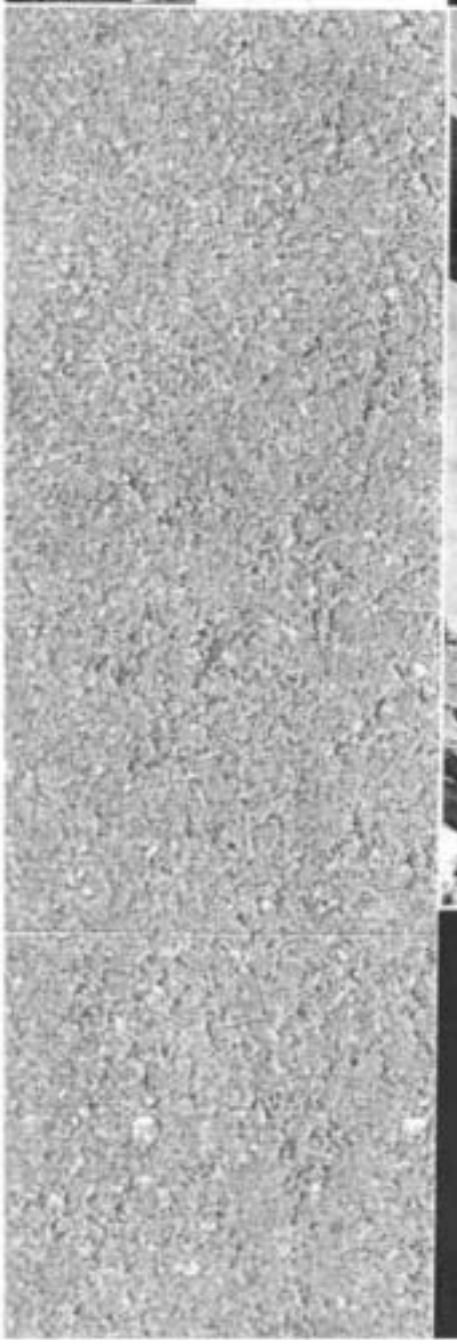
Sales Offices located across Canada

PRINTED IN CANADA 01/02

TERCEM 3000

TECHNICAL BULLETIN

Blended Cement for Performance Concretes



LAFARGE
NORTH AMERICA

Table of Contents

List of Figures:

Appendixes:

Tercem 3000™ Cement

Lafarge Tercem 3000™ cement, a new ternary composite cement, is the ideal product when concrete requires additional strength and durability. Concrete containing this product also has superior finishing qualities. Tercem 3000™ is produced by intergrinding Portland cement clinker, gypsum, silica fume and pelletized blast-furnace slag. The proportions of supplementary cementing materials are in the range of 4 to 6% silica fume and 20 to 25% slag; a typical chemical analysis is shown in Table 1. The precise proportions are optimized for performance and to produce a cement suitable for a wide variety of applications. The benefits of using Tercem 3000 in concrete include:

- Improved compressive strength
- Lower permeability
- Improved rheology and pumpability
- Reduced concrete bleeding
- Improved finishability
- Enhanced durability

The principle use for Tercem 3000™ is in concrete flatwork. In applications such as roads, sidewalks, driveways, curbs and gutters, and industrial, commercial, and institutional floors this product provides the desired finishing characteristics in the plastic concrete and is ideally suited for situations during warm weather. The reduced permeability in the hardened concrete results in improved durability. Other uses for this product include foundation walls, precast concrete products, and roller-compacted concrete. Tercem 3000, easier to place and finish due to its improved rheology, reduces bleeding and has excellent slipforming qualities. During periods of excessive evaporation precautions should be taken to protect the concrete surface from rapid evaporation.

Tercem 3000™ meets the requirements in CSA A3000-98 A362 Blended Hydraulic Cement for the following types of ternary blended cement (see Appendix 1):

- Type 10E-S/SF
- Type 20E-S/SF
- Type 50E-S/SF

This means that Tercem 3000™ provides equivalent performance to Type 10 Normal Portland cement, Type 20 Moderate Portland cement and Type 50 Sulphate-resistant Portland cement.

Tercem 3000™ also meets the requirements in ASTM C 1157M-97 Standard Performance Specification for Blended Hydraulic Cement for the following types (see Appendix 2):

- Type GU – Blended hydraulic cement for general construction (general use)
- Type HE – High Early Strength
- Type MS – Moderate Sulfate Resistance
- Type HS – High Sulfate Resistance

Table 1

Typical Chemical Analysis of Portland Cement and Blended Hydraulic Cements

	Type 10	Tercem 3000™
SiO_2	20.2	26.3
Al_2O_3	4.7	5.6
Fe_2O_3	2.1	1.9
CaO	63.3	56.2
MgO	2.8	4.8
Na_2Oe	0.87	0.89
SO_3	3.3	2.9
LOI	1.9	0.7
Blaine (m^2/kg)	380	580
S.G.	3.15	3.07
C_3S	61	–
C_2S	12	–
C_3A	9	–
C_4AF	6	–

1. Cementitious Components

1.1 Portland Cement

The Portland cement clinker used in the manufacture of Tercem 3000™ is also used for the production of normal Portland cement. The same clinker is also used in the manufacture of Lafarge SF™ cement, which meets the requirements of CSA A3000-98 A362 Blended Hydraulic Cement for Type 10E-SF. Chemical analyses for Type 10 and Tercem 3000™ are shown in Table 1.

1.2 Silica Fume

The silica fume used in Tercem 3000™ comes from the condensation of SiO vapour produced in an electric arc furnace during the production of silicon metal and ferrosilicon alloys. It complies with the requirements of CSA A3000-98 A23.5 *Supplementary Cementing Materials* for a Type SF material. In its natural state, silica fume is an extremely fine powder with particles having an average diameter of about 0.1 μm. For easier handling and to ensure a uniform feed in the grinding mill the silica fume is pelletized with water. This process is most efficient for producing a homogenous blended cement of constant quality and with good handling characteristics. During the intergrinding process, the heat generated in the mill drives off the moisture returning the pelletized silica fume to its original fineness.

Silica fume is composed of very small (about 100 times finer than the average cement particle) spherical particles, which are composed almost entirely of amorphous silica (typically > 90% SiO_2). This makes the silica fume a highly reactive pozzolan. It will react with the calcium hydroxide, $Ca(OH)_2$, released during the hydration of Portland cement, to produce calcium-silicate-hydrates, C-S-H, similar to those produced by Portland cement. The production of the additional C-S-H leads to increased strength and reduced porosity and permeability in the hardened material. Furthermore, the hydration products produced are capable of absorbing a substantial quantity of alkalis thereby reducing the amount available for deleterious reaction with certain types of aggregate.

As a result of these benefits concrete produced with silica fume has enhanced strength and durability compared with normal concrete.

The properties of silica fume and silica fume concrete are documented in the ACI Committee 234 Report "Guide For the Use of Silica Fume in Concrete."

1.3 Slag

The slag used in the production of Tercem 3000™ complies with the requirements of CSA A3000-98 A23.5 *Supplementary Cementing Materials* for a Type S material. The slag originates from blast furnaces used in the manufacture of iron. To make the product suitable for use in concrete, the molten slag is rapidly cooled by pelletization prior to intergrinding. This produces a glassy (amorphous) material that is predominantly composed of silicates and alumino-silicates of calcium (and to a lesser extent magnesium). Ground granulated (iron) blast furnace slag is a latent hydraulic material that produces hydrates that are similar to Portland cement.

Slag has been used as a cementitious material in concrete for more than 100 years. It is well established that its use can improve many of the properties of concrete ultimately leading to improved long-term strength and durability.

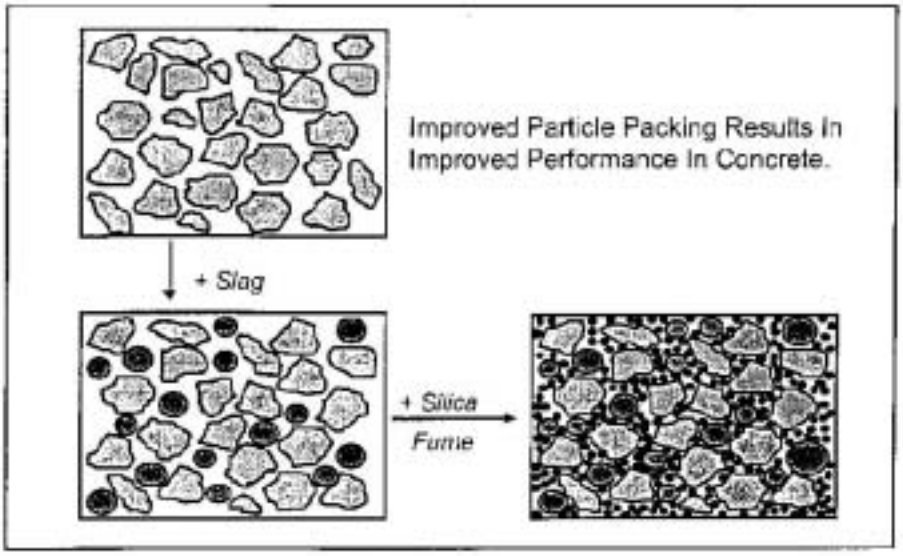
The properties of slag and slag concrete are documented in the ACI Committee 233 Report "Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete and Mortar."

2. Benefits of Ternary Blended Cement

The production of a cement blend incorporating two supplementary cementing materials (SCM's), such as silica fume and slag, can result in synergistic effects because of the different nature of the SCM's. For example, the following benefits have been observed when silica fume and slag are used in combination with Portland cement:

- The resulting particle size distribution leads to an improved particle packing of the cement.
- Silica fume compensates for the comparatively low early-strength of concrete with slag.
- Slag increases long-term strength development of silica fume concrete.
- Slag improves the finishing properties of silica fume concrete. (i.e. reduces stickiness)
- Silica fume reduces the normally high levels of slag required for sulphate resistance and ASR mitigation.
- Slag can reduce the heat of hydration of silica fume concrete.
- Very high resistance to chloride ion penetration can be obtained with combinations of silica fume and slag.

The benefits associated with the use of ternary blends has made Tercem 3000™ the first choice for the production of a wide range of concretes including high-performance concrete.



3. Properties of Fresh Concrete

3.1 Workability and Cohesion

Concrete containing Tercem 3000™ has the similar water demand as an equivalent concrete produced using Type 10 Normal Portland cement; i.e. the same water content is required for a given slump. However, the use of Tercem 3000 increases the cohesiveness of the mix resulting in reduced segregation and bleeding.

3.2 Pumpability

The pumpability of concrete has been found to be significantly improved when using Tercem 3000™ cement as the presence of silica fume and slag have a lubricating effect (reducing pump pressures by up to 50%) while reducing the risk of segregation during pumping.

3.3 Time of Setting

Concrete produced with Tercem 3000™ cement shows the same setting behaviour as concrete produced with Type 10 cement made from the same Portland cement clinker. Also, the use of Tercem 3000™ reduces bleeding, which usually enables finishing operations to be carried out earlier.

3.4 Air Entrainment

Air contents (and spacing factors) of concrete made with Tercem 3000™ should be the same as normal Portland cement concrete for similar exposures. Small adjustments in the dosage of air-entraining admixtures may be required when changing the type of cement used for concrete production.

3.5 Compatibility with Admixtures

Tercem 3000™ cement is compatible with most conventional admixtures such as water reducers, superplasticizers, retarders, accelerators, air entrainers, and other types of admixtures. To obtain optimum performance with these admixtures, slight adjustments in the dose rate may be required. Technical representatives of Lafarge or the admixture supplier can provide advice in this regard.

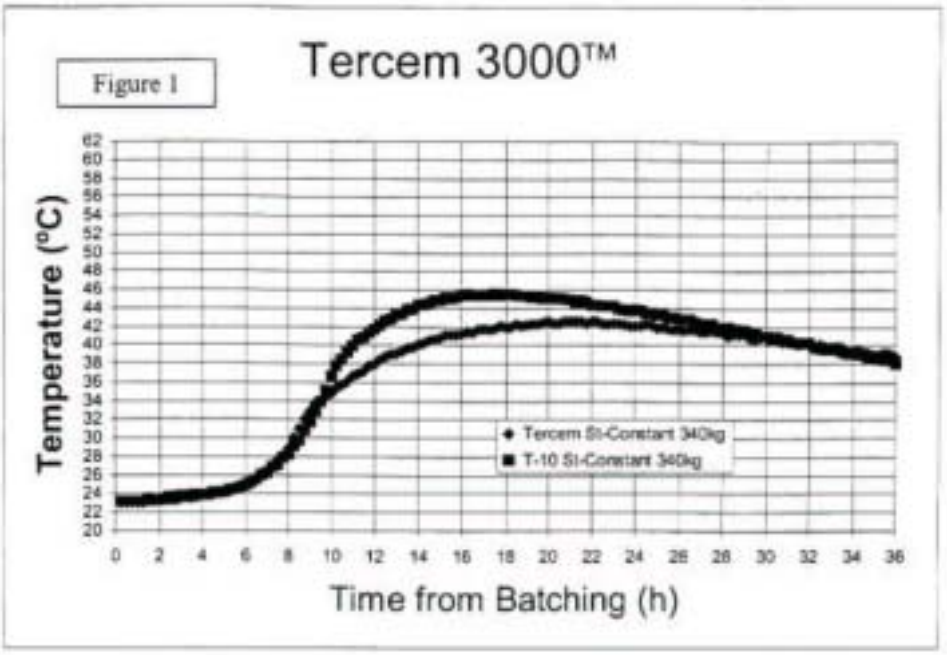
3.6 Plastic Shrinkage

The potential for plastic shrinkage of concrete containing Tercem 3000™ cement is similar to that for concrete with Type 10 cement.

3.7 Hydration Temperatures

For a given cementitious material content, concrete made with Tercem 3000™ cement produces the same or slightly less heat than concrete made with a Type 10 cement produced from the same clinker (Figure 1). Further reductions in temperature rise can be achieved by partial replacement of Tercem 3000™ with fly ash or slag at the concrete production facility.

Figure 1

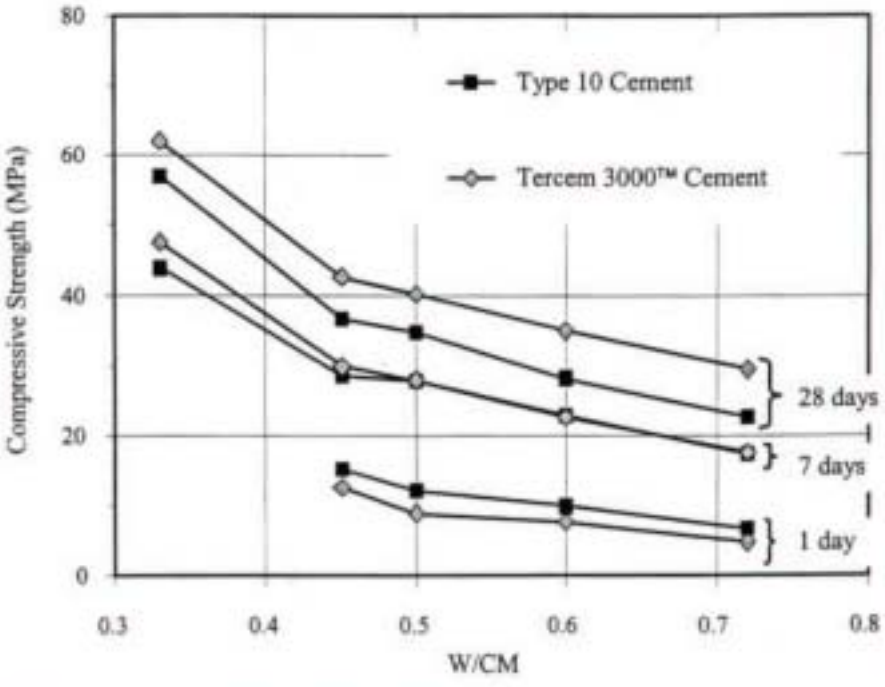


4. Properties of Hardened Concrete

4.1 Compressive Strength

Concrete produced with Tercem 3000™ cement has a higher compressive strength at 28 days (and beyond) compared with concrete produced with the same quantity of ordinary Type 10 Portland cement and the same water to cement ratio (W/CM). The early age strength (e.g. at 1 day) may be slightly lower in the concrete produced with Tercem 3000™ cement because of the incorporation of slag. Figure 2 shows strength results for a range of concrete mixes (W/CM between 0.33 and 0.72) at different ages. For normal strength concrete, the use of Tercem 3000™ cement typically results in a 10 to 20% increase in the 28-day compressive strength compared with Type 10 cement.

Figure 2: Compressive Strength Development of Concrete



4.2 Permeability

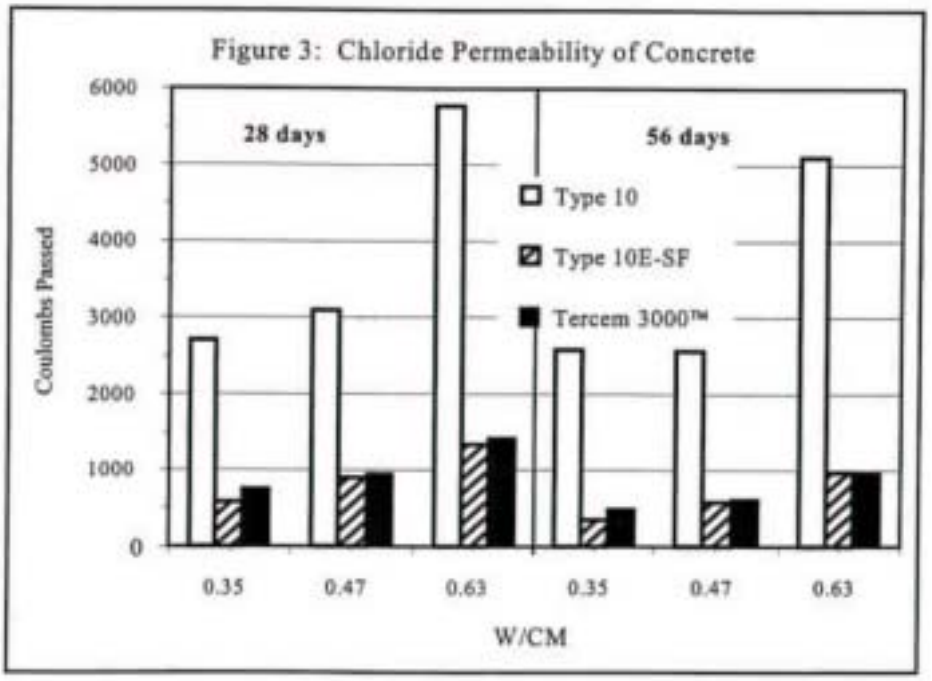
The combination of silica fume and slag produce significant reductions in the permeability of the concrete to water, gases and deleterious agents (e.g. chlorides and sulphates). These effects are attributed to the pozzolanic reaction, reduced porosity, improved quality of the interface between the cement paste and the aggregate, and reduced internal bleeding.

The permeability of concrete to chloride ions is often measured using ASTM C 1202 *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*, which is more commonly referred to as the Rapid Chloride Permeability or RCP Test. This test ranks the permeability of the concrete on the basis of the electrical charge passed during the six-hour test as follows:

Charge Passed (Coulombs)	Chloride Ion Penetrability
> 4,000	High
2,000 – 4,000	Moderate
1,000 – 2,000	Low
100 – 1,000	Very Low
< 100	Negligible

Figure 3 shows the results from a series of concretes of varying water to cement ratios (W/CM from 0.35 to 0.63) cast with three different cements, which were produced from the same Portland cement clinker. The use of Tercem 3000 significantly reduces the permeability compared with Type 10 Portland cement and generally produces performance that is equivalent to silica fume cement (Type 10E-SF).

Figure 3: Chloride Permeability of Concrete



5. Durability of Concrete with Tercem 3000™

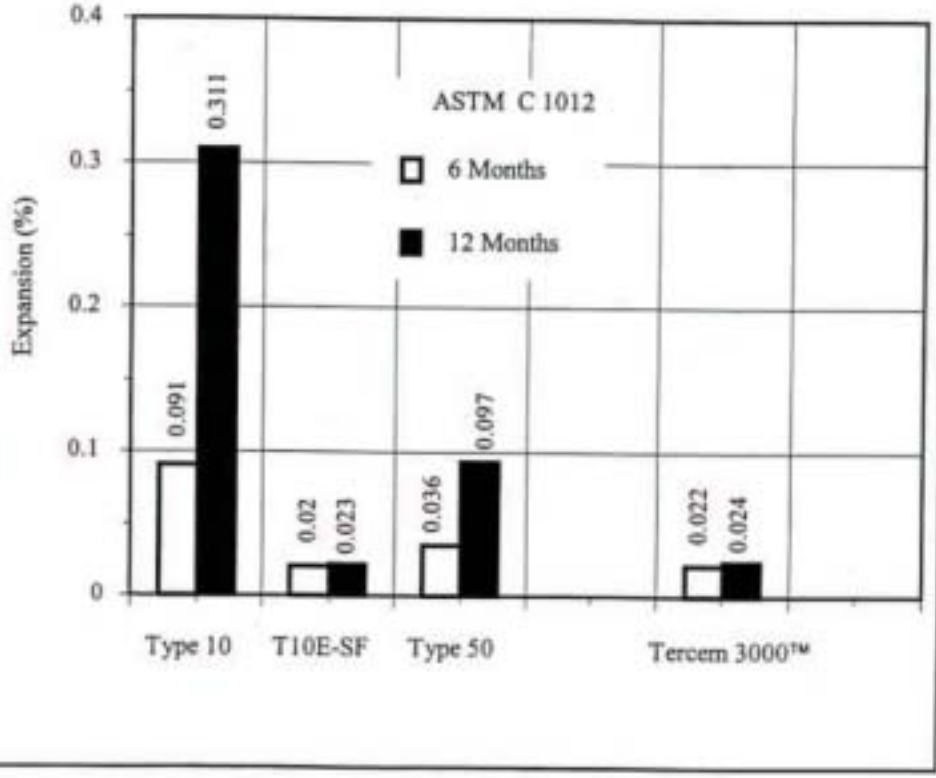
5.1 Resistance to Sulphate Attack

Tercem 3000™ cement provides excellence resistance to sulphate attack as demonstrated by its performance in ASTM C 1012 *Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution.* Figure 4 shows test data for mortars cast with three different samples of Tercem 3000™ and for mortars cast with Type 10 cement and Type 10E-SF cement produced from the same clinker.

Tercem 3000™ cement shows equivalent performance to, a silica fume cement, (Type 10E-SF) with higher amounts of silica fume and meets the requirements of both the CSA Specification (CSA A3000-98 A362) and the ASTM Specification (ASTM C 1157) for high sulphate resistance.

The high sulphate resistance is attributed to the combined action of the silica fume and slag which, leads to a reduction in permeability and an increase in chemical resistance due to the consumption of calcium hydroxide by the pozzolanic reaction.

Figure 4: Results of Sulphate Resistance Tests



5.2 Resistance to Cycles of Freezing and Thawing

Laboratory testing using ASTM C 666 *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing* indicates that air-entrained concrete produced with Tercem 3000™ cement has excellent resistance to cyclic freezing and thawing with durability factors in excess of 95% after 300 cycles. It is recommended that the minimum air contents and maximum spacing factors of the relevant CSA or ACI specifications be followed regardless of the cement type.

The scaling resistance of concrete exposed to cycles of freezing and thawing in the presence of de-icing salts is affected by both the quality of the concrete (e.g. W/CM) and the quality of the air-void system. Laboratory tests using ASTM C 672 Standard Test Method for Scaling Resistance of Concrete Surfaces to De-icing Chemicals indicate that concrete meeting the requirements of CSA A23.1 for air entrained concrete will have excellent scaling resistance when produces with Tercem 3000™ cement.

Additional testing carried out according to Norme Quebec NQ 2621-900 have also indicated an excellent scaling resistance with only 0.09 kg/m3 of material loss (limit of 0,50 kg/m3) at a cement content of 340 kg/m3.

5.3 Resistance to Alkali-Silica Reaction

The use of either, silica fume or slag, in concrete has been shown to reduce the risk of damage due to alkali-silica reaction. When these two materials are used together (i.e. in a ternary blended cement) there is a synergistic effect, with the combination showing a greater efficacy in terms of controlling expansion[1].

The ability of Tercem 3000™ to control ASR expansion has been tested using the concrete prism expansion test (CSA A23.2-14A) and the results are shown in Figures 5 and 6 for moderately reactive and highly reactive aggregates, respectively. In these tests the alkali content of the blended cement was raised to 1.25% equivalent sodium oxide (Na_2Oe) by adding NaOH to the mixing water. This is a somewhat more severe test condition than that prescribed in CSA, which only requires the Portland cement component to be raised to 1.25% Na_2Oe. Even with the additional alkali content (which results is a 12% increase in alkali over that specified in CSA), Tercem 3000 is effective in reducing expansion to below the CSA specified limit of 0.040% at 2 years with both reactive aggregates.

---

[1] Bleszynski, R.F., Thomas, M.D.A. and Hooton, R.D. "Use Of Ternary Blended Cements To Control ASR." Proceedings of the 11th International Conference on Alkali-Aggregate Reaction in Concrete, Quebec City, June 2000.

Figure 5 Expansion with Moderately-Reactive Aggregate

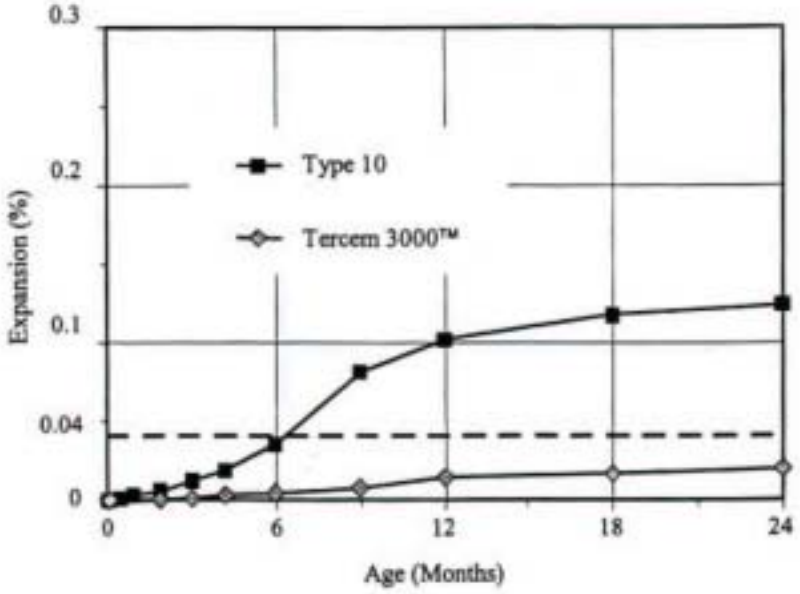
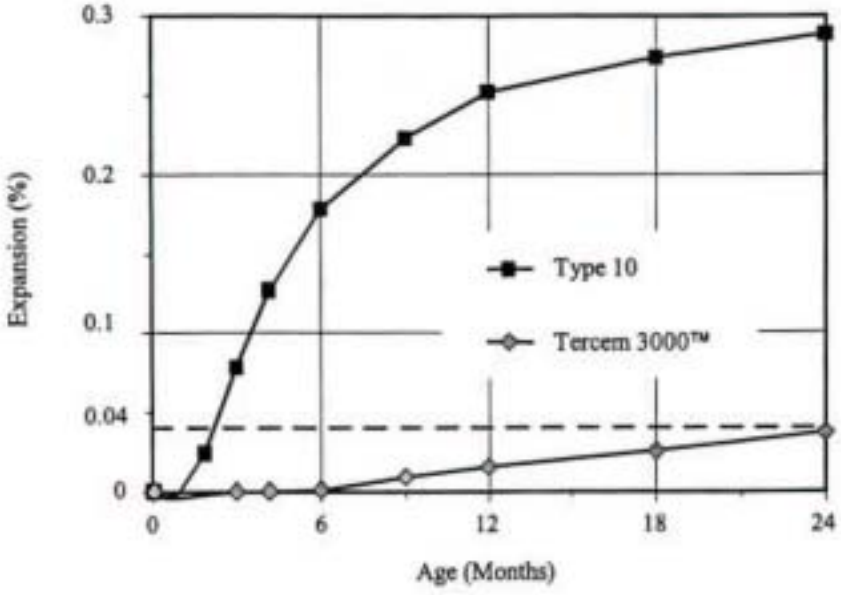


Figure 6 Expansion with Highly-Reactive Aggregate



The long-term performance of concrete containing a ternary blend of high-alkali cement, silica fume and slag in terms of controlling expansion with a highly reactive aggregate and resisting the action of salt scaling has been confirmed in a field exposure study. In this study, concrete beams and slabs produced with a highly reactive aggregate and high-alkali cement were exposed at an outdoors exposure site. After 10 years, the use of silica fume (3.5% replacement) and slag (25% replacement) was found to be the most effective measure tested in terms of controlling the expansion of beams and scaling of the slabs.

Although, Lafarge endorses the use of Tercem 3000™ cement with moderately reactive aggregates, the company does not recommend the use of Tercem 3000 with aggregates that are classified as highly reactive by the current edition of CSA A23.1, 27A - *Standard Practice to Identify Degree of Alkali-Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete.* The procedures in the current edition of CSA A23.1 27A should be followed when using supplementary cementing materials (including blended cements) with potentially reactive aggregate.

Appendix 1

Physical Requirements of Blended Hydraulic Cement in CSA A362

& Comparative Performance of Tercem 3000™

	10E	20E	30E	40E	50E	Tercem 3000™
Fineness (maximum % retained on 45 µm sieve)	24.0	24.0	24.0	24.0	24.0	10.0
Autoclave expansion (max %)	0.8	0.8	0.8	0.8	0.8	0.045
Time of Set (minutes)						
Minimum	45	60	45	90	60	125
Maximum	480	480	250	480	480	
Strength (minimum MPa)						
1 Day	–	–	13.5	–	–	11.1
3 Days	14.5	14.5	24.0	8.5	14.5	23.7
7 Days	20.0	20.0	–	–	20.0	33.7
28 Days	26.5	26.5	–	25.0	26.5	48.9
Heat of Hydration (maximum kj/kg at 7 days)	–	300§	–	275	–	319
Sulphate Resistance (% maximum exp. at 6 months)	–	0.10§	–	–	0.05	0.037

§ Requirement of either heat of hydration (or both) shall be specified at the option of the purchaser

Appendix 2

Physical Requirements of Blended Hydraulic Cement in ASTM C 1157

& Comparative Performance of Tercem 3000™

	GU	HE	MS	HS	MH	LH	Tercem 3000™
Autoclave Expansion (maximum %)	0.8	0.8	0.8	0.8	0.8	0.8	0.045
Time of Set (minutes)							
Minimum	45	45	45	45	45	45	125
Maximum	420	420	420	420	420	420	
Strength (minimum MPa)							
1 day	–	10	–	–	–	–	11.1
3 days	10	17	10	5	5	–	23.7
7 days	17	–	17	10	10	5	33.7
28 days	–	–	–	17	–	17	48.9
Heat of Hydration (maximum kj/kg)							
7 days					290	250	319
28 days					–	290	
Mortar Bar Expansion (maximum % at 14 days)	0.020	0.020	0.020	0.020	0.020	0.020	0.003
Sulfate Resistance (maximum %)							
6 months			0.10	0.05			0.037
12 months			–	0.10			