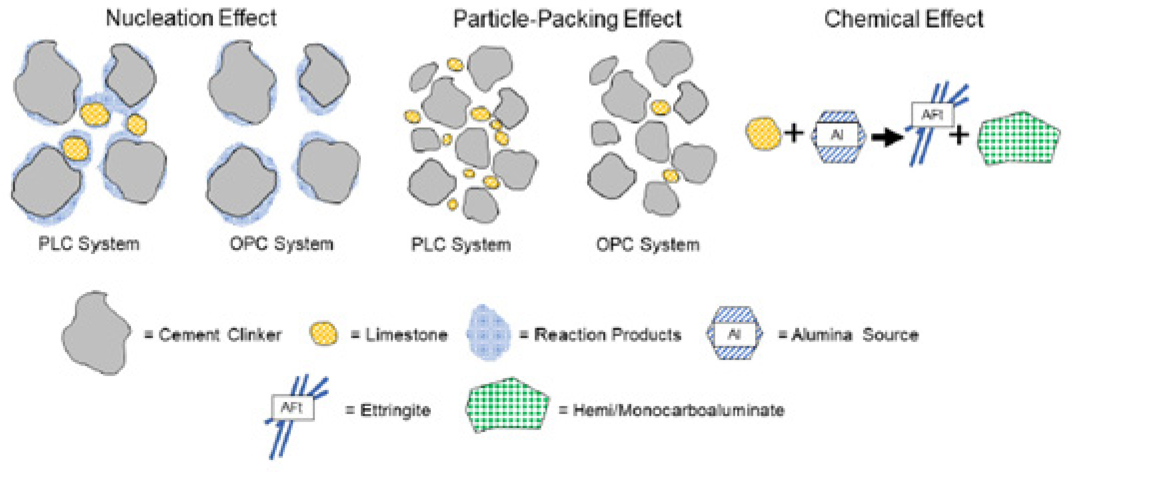
Portland-Limestone Cement Primer

Portland-Limestone Cement (PLC) is manufactured in compliance with CSA A3001 - Cementitious Materials for Use in Concrete. PLC includes a variety of different types of cement as noted in Table 1 of this document. This primer focuses on General Use Limestone cement (GUL). The specifications for using GUL in concrete production are outlined in the CSA A23.1 - Concrete Materials and Methods of Concrete Construction Standard. GUL is a type of PLC that provides a lower-carbon alternative for concrete production compared to General Use cement (GU). Unlike GU cement, which contains up to 5% limestone interground with clinker, GUL cement includes up to 15% limestone, which reduces clinker content and, in turn, lowers the concrete's embodied carbon emissions.

How is GUL made?

To achieve performance similar to GU cement, GUL is generally ground to a finer particle size during manufacturing. Figure 1 illustrates the mechanisms that enable GUL to perform comparably to GU cement. The increased fineness provides additional nucleation sites for clinker reactions and accelerates early-age hydration reactions. Enhanced particle packing occurs through the filler effect, and a portion of the limestone in GUL reacts with aluminate phases, both further decreases concrete porosity. Research in Canada and the U.S. has shown that, with proper design, GUL can effectively replace GU cement with minimal impact on concrete performance. Adjustment in the required dosages of chemical admixtures and other concrete ingredients might be required and should be properly tested and assessed.

Figure 1: Illustration – The Nucleation, particle-packing and Chemical Effects



Source: FHWA.

GUL cements have shown enhancement of the pozzolanic reactions when combined with SCM, particularly improved with those which have high alumina content.

Generally, GUL-based concrete demonstrates comparable properties to GU concrete at 28 days, including compressive strength, flexural strength, elastic modulus, shrinkage, resistance to chloride penetration, resistance to alkali-silica reaction, scaling resistance, and sulfate attack resistance. However, there may be slight differences in fresh concrete properties; for example, GUL-based concretes may show minor reductions in workability, shortened setting times, and slower bleed rates, potentially extending the time needed between placement and finishing. GUL-based

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concrete can be placed using the same equipment and procedures contractors currently employ. Like GU cement, GUL cement performs effectively with the SCMs available in the Canadian market, enhancing opportunities for low-carbon concrete.

Most Canadian cement producers now primarily produce GUL-based cements. Overall, GUL cement has effectively replaced GU cement in concrete applications with minimal adjustments to existing practices and methods. This document is intended to support the transition from GU to GUL- based concrete and to help address any challenges that may arise.

History of Portland-Limestone Cement

GUL based cements have been used in Europe for over 35 years and have a long-established record of field performance in a variety of exposure conditions and applications. . European cement standards allow up to 35% limestone content in GUL, which can restrict the use of such concrete mixes to select applications. Canadian standards have set the inclusion of limestone in GUL to be up to 15% in order to maintain equivalent performance when compared to traditional GU concretes.

Research on GUL with Canadian source materials began in 2006, prior to GUL's introduction to the Canadian Standards Association (CSA) cementitious materials standard in 2008 and concrete materials standard in 2009. In 2012, ASTM C595 and AASHTO M240 standard specifications for blended hydraulic cements started allowing up to 15% blended or interground limestone to be used in binary blended cements.

Canadian Specifications for GUL

The definition and specifications for GUL are contained in the CSA A3001 Cementitious Materials for Use in Concrete. The specifications for using GUL in manufacturing concrete are contained in the CSA A23.1 Concrete Materials and Methods of Concrete Construction Standard.

CSA A3001 defines PLC and specifies its requirements in Clause 4.1, as highlighted in Table 1. "The proportion of limestone in PLC shall be > 5% and ≤ 15% by mass", and performance limits are the same as for traditional Portland cement of the same type.

Table 1: Extraction from CSA A3001 Cement Types

Name	Portland cement type	Portland-limestone cement type‡	Blended hydraulic cement type	
			Blended portland cement*	Blended portland-limestone cement†
General use cement	GU	GUL	GUb	GULb
Moderate sulphate-resistant cement	MS	MSL	MSb	MSLb
High early-strength cement	HE	HEL	HEb	HELb
High sulphate-resistant cement	HS	HSL	HSb	HSLb

** The suffix "b" indicates that the product is a blended portland cement.*
† The suffix "Lb" indicates that the product is a blended portland-limestone cement.
‡ The suffix "L" indicates that the product is portland-limestone cement.

Note: Moderate and low heat of hydration cement types were removed as part of the latest CSA A3000 amendment in May 2021.

How is GUL manufactured?

The manufacturing processes for GUL and GU cement are similar with the main difference being the greater proportion of clinker being replaced with interground limestone for GUL. Typical interground limestone contents for GUL are 10 to 15 percent compared to 2 to 4 percent for GU. The added limestone is blended or interground with clinker and gypsum. Limestone has a lower hardness than clinker, so it is typically ground to a finer particle size.

The increased limestone content in GUL and changes in fineness may necessitate adjustments to the gypsum content. (Research by Campiteli and Florindo). Although GUL cement is engineered to optimize performance and balance all aspects previously mentioned, trial batches are recommended to verify that concrete performance requirements are met.

GUL manufacturing offers additional advantages over GU, including reduced CO2 emissions, lower energy consumption, and extended quarry life.

Performance of GUL based concrete

The CAC document entitled Introduction of PLC in Municipal and Provincial Construction Specifications highlights the research undertaken in Canada by Professors Mike Thomas and Doug Hooton comparing GU and GUL based concretes for strength, freeze-thaw durability, scaling resistance, resistance to chloride penetration, mitigation of alkali aggregate reactivity, shrinkage, and sulphate exposure. The research showed the two types of cement, GU and GUL, performed similarly in all the performance criteria. A 2021 CALTRANS PLC study agreed with these findings noting that GUL cement performed similar to, or better than, GU cement for sulfate exposure, shrinkage, mitigating alkali silica reactivity and resistance to chloride penetration.

The FHWA TECHNOTE on Portland Limestone Cement (FHWA-HRT-23-104) document discusses the fresh properties (workability, bleeding and setting time) and mechanical properties of GU and GUL based concretes. This report highlights that it is not possible to establish a general rule for all cases. Testing of concrete incorporating the specific raw materials should be performed prior to delivering the mix.

1) Comments on fresh properties (workability, bleeding, and setting time) were as follows:

a. GUL based concrete bled less than GU based concrete. Reduction in bleeding is associated with the increased surface area of the finer ground GUL cement.
b. Research on setting time shows different results ranging from no influence to a significant decrease in setting time.
c. When SCMs are combined with GUL the reduction in initial and final setting times may become more significant.
d. Differences in limestone mineralogical composition, replacement levels and fineness might generate varied outcomes in terms of fresh properties.

2) Comments on Mechanical Properties were as follows:

Volume Stability – "Drying shrinkage measurements have been generally found to be statistically similar in comparisons of GU and GUL. One exception, as identified by Bharadwaj et al., regarded the use of GUL in combination with slag, which exhibited increased total shrinkage (7 to 8-percent increase). The researchers attributed the observed shrinkage increase to enhanced slag reactivity induced by the additional limestone. Barrett, Sun, and Weiss found an average increase in 28-d drying shrinkage of 5 percent when GUL concrete specimens were compared with equivalent GU concrete." FHWA TECHNOTE

Durability – "The durability indicators of PLC systems have been generally found to be similar to mixtures made with GU. Thomas et al. reported similar freeze–thaw performance, scaling, and chloride transport for GUL systems. Barrett, Sun, and Weiss observed that transport properties in GUL concrete were within +/- 30 percent of comparable GU concrete mixtures. Alkali–silica reaction and sulfate testing showed that GUL concretes perform similarly to or better than GU concretes. The measured porosity, formation factor, and apparent chloride diffusion coefficient of GUL concretes were found to be comparable to those obtained for equivalent GU concretes." FHWA TECHNOTE

Best Practices

FHWA publication number, FHWA-HRT-23-104 states, "to help mitigate potential implementation challenges with using PLC the following best practices have been recommended by industry members:

- Performing trial batches using the same aggregates, SCMs and admixtures that are planned for use in the field can improve understanding of water demands, setting time, and strength development prior to actual placement.
- Use tools such as maturity or temperature match curing to monitor concrete strength development for projects in which strength development is critical.
- As with GU or GUL, consider the effects of temperatures on the reactivity of the material. Be prepared to use extra precaution with heating blankets or other cold-weather concreting techniques when temperatures are low.
- Conversely, for both GU and GUL cement hot weather can exacerbate reductions in workability. Adjust the mixture accordingly during trial batching and field concrete mixing to account for job site temperatures.
- Use tools such as calorimetry to investigate the early-age reaction behavior of the GUL or the GUL in combination with the anticipated admixtures and SCMs. Calorimetry can provide information on the early-age behavior of concrete, including estimations of setting time and temperature development. Use such information to adjust the concrete mixture design during qualifying operations or whenever field performance does not meet expectations.
- Use mockups or monitoring technologies to determine the optimal time between placing and finishing. Make contractors aware that the bleed rate is lower and that a visual determination of when to finish the concrete may result in adverse performance.
- Communicate early and often with cement and concrete suppliers to identify when the transition from GU to GUL will occur and how the transition could affect projects
- Evaluate production variation (e.g., strength or air content) prior to transitioning from GU to GUL to provide an understanding of within-plant product variations. The use of GU production variation data can help inform evaluation of GUL production variation." FHWA TECHNOTE

References

a) FHWA TECHNOTE, Portland Limestone Cement, FHWA-HRT-23-104,Turner-Fairbank Highway Research Center, October 2023

b) Cement Association of Canada, Technical Introduction to Portland-limestone Cement for Municipal and Provincial Construction Specifications, March 2025, v2.1