EXECUTIVE SUMMARY

Portland-limestone cement (PLC), or Type IL cement, is a cement formulation based on portland cement clinker, with additional limestone used as an ingredient in amounts up to 15% by mass. The environmental benefits of cements with limestone are appreciable: because less limestone is calcined to produce the clinker for a given amount of PLC, both calcination and fuel combustion CO_2 emissions are reduced. Although more grinding energy can be required compared to portland cements, the energy saved by reducing clinker in the finished cement outweighs the extra grinding energy. The 2021 industry-wide environmental product declarations (Portland Cement Association and ASTM International 2023a, 2023b), show that on average, a portland-limestone cement (averaging 10.8% limestone content) has an 8.2% lower carbon footprint than a portland cement in the U.S.

There is a wealth of published literature related to the use of limestone as an ingredient in portland-limestone cements. This literature includes both laboratory research studies and real-world installations.

Use of Limestone in Cement

Uncalcined (unfired) ground limestone has a long history of use in cement. Cements containing limestone have been used throughout Europe and in other countries since the 1960s. Following the adoption of EN 197-1 in 2000, use of PLC in Europe grew steadily. Canadian specifications in the CSA A3000 compendium have permitted limestone as an ingredient in portland cements since 1983 and contained provisions for PLCs since 2008.

In the U.S., limestone has been permitted as an ingredient in amounts of up to 5% in ASTM C150 portland cements since 2004 (AASHTO approved a similar change to M 85 in 2007). In 2012, requirements for PLC (Type IL) with up to 15% limestone were defined in blended cement specifications ASTM C595 and AASHTO M 240, and these cements have seen increasing availability and acceptance in recent years. Experience with blended cements containing limestone has demonstrated that they can be used to produce strong, durable concretes and mortars. (Though not allowed for general concrete construction, C91 masonry cements with ground limestone as a significant ingredient have been available since the 1920s and historically account for about 70% to 80% of cements for mortar.)

Manufacture of PLC

Portland-limestone cements are typically developed by cement manufacturers to perform comparably to portland cement in concrete and other cement-based materials. Numerous research studies demonstrate that fresh and hardened concrete properties of PLC concrete are comparable to concretes made with portland cement. Optimization techniques for PLC production include controlling cement fineness and sulfate content that provides for comparable performance when compared to portland cement made from the same clinker.

Performance of PLC

Research studies and real-world installations have demonstrated that by following well-documented mixture design and quality control practices, concretes made using PLC can perform

similarly to concretes made with portland cement. Although relatively inert compared to clinker or supplementary cementitious materials (SCMs), limestone contributes directly to properties through three mechanisms:

• Particle packing effects, which can reduce water demand (and therefor water-to-cement ratios for equivalent workability) and subsequently increase strengths,

• Nucleation effects, in which hydration products of traditional cement reactions are accelerated slightly,

• Limestone chemical reactions, while minor, can produce carboaluminate phases, which can reduce porosity.

As durability of concrete is a primary concern in many applications, it is important to note that the same techniques used to provide properties such as freeze-thaw or sulfate resistance for portland cement mixtures are also used with PLC mixtures. Just like concrete made with portland cements, concrete made with PLC should be tested to confirm fresh and hardened properties such as air void content, strength, freeze-thaw durability, and sulfate resistance. For sulfate resistance, laboratory and simulated field exposure research results confirm that use of supplementary cementitious materials (SCMs) in combination with PLCs can produce highly sulfate-resistant concrete suitable for severe sulfate exposures. Performance testing of PLCs and PLC-SCM combinations is required to qualify the sulfate resistance characteristics of the cementitious system. In addition, some cement manufacturers also produce ASTM C595/AASHTO M 240 Type IL(MS) or Type IL(HS) cements, which have been tested (in accordance with ASTM C1012) to demonstrate moderate or high sulfate resistance, respectively, and can be used in similar applications to ASTM C150/AASHTO M 85 Type II or Type V cements.

PLC Acceptance

Both the availability and acceptance of PLCs have increased over the past decade.

Beginning in early 2021, U.S. Geological Survey (USGS) cement shipments data show that the share of blended cements relative to total cement shipments increased sharply in the U.S. While the blended cement category includes Type IP (portland-pozzolan), Type IS (portland blast-furnace slag), Type IL (portland-limestone), and Type IT (ternary blended) cements, the strong uptick in blended cement production is the result of increased shipments of PLC (Type IL) more than the other cement types, with the USGS estimating that more than 95% of U.S. blended cement is PLC. Over the past decade, technical research and communication efforts resulted in acceptance of PLC by major customer and specifier groups like the state Departments of Transportation (50 accepted its use by February 2024), users of AIA MasterSpec, Unified Facilities Guide Specifications (UFGS), the Federal Aviation Administration, and others. USGS data indicate that more than 52 MMT of PLC was consumed in 2023.

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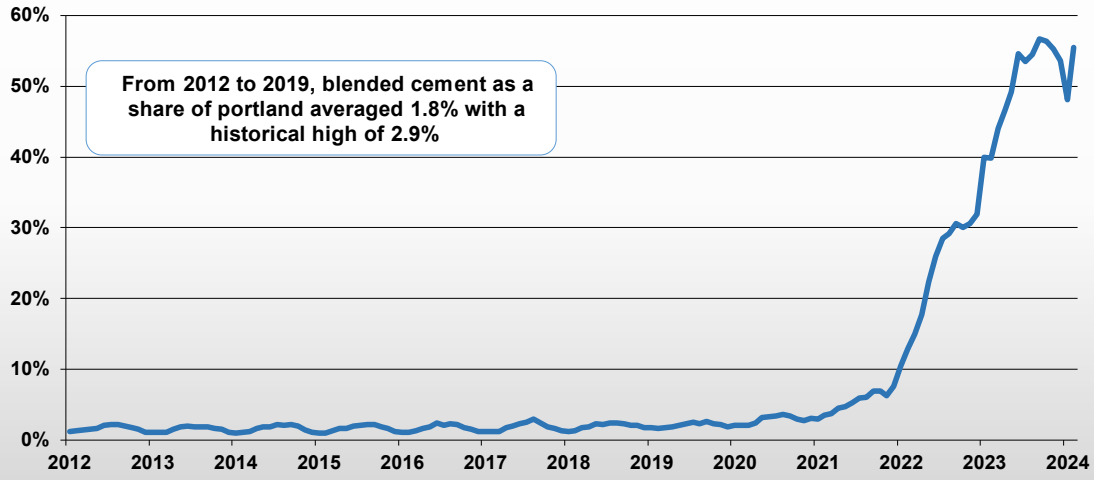
Blended Cement as a Share of Total Cement - US



Source: USGS