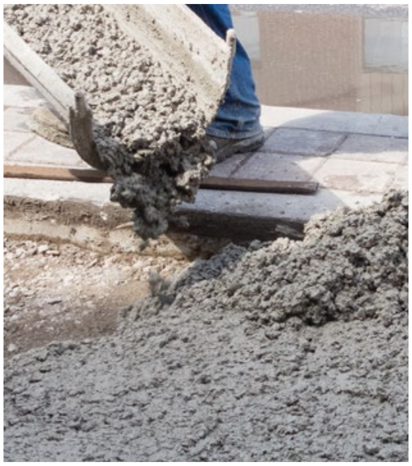
TECHNICAL BULLETIN AD-08

WHAT IS PLC OR TYPE IL?

EUCLID CHEMICAL

A Greener Cement Option



There are many ways to improve the sustainability of construction practices, including more efficient use of natural resources, better thermal performance of structures, and reduced environmental impact of construction materials. Like all building materials, portland cement has an environmental footprint, and it's often described in terms of "embodied carbon", or all the carbon dioxide (CO_2) emitted in its production. Cement is made by grinding clinker, the main energy intensive ingredient, to a fine powder. Producers know that replacing some of the clinker in portland cement with ground limestone offers environmental benefits, the most important being that it reduces the embodied carbon of the cement.

The global cement industry has been working on reducing their carbon footprint for many years as shown in the timeline on the next page. The Canadian cement industry, which has been intergrinding 5% limestone filler in their OPC (Ordinary Portland Cement) since the 1980's, was mandated to reduce their carbon footprint by 10% by the federal government. They responded with the new PLC, a cement that incorporates up to 15% limestone fillers. In 2012, the American industry incorporated this type of cement at ASTM under the ASTM C595/AASHTO M 240 blended cement which allows up to 15% limestone fillers in the cement.

PLC/Type IL is governed by ASTM C595/AASHTO M 240, *Standard Specification for Blended Hydraulic Cements*, (5% OPC in Canada since the 1980s and now in USA with up to 15% limestone by mass) and is proven cement technology that can be used to build with concrete confidently and sustainably at the same time.

How is it made?

PLC is made by blending or inter-grinding regular clinker with up to 15% limestone. While regular portland cement contains up to 5% limestone, PLC is a finer-ground product than regular portland cement. Limestone is softer and finer than clinker, with limestone being ground to an estimated 6 microns and cement ground to 15-20 microns. The Blaine fineness of PLC Type IL, although not a perfect measurement because limestone does not pack exactly like cement, is in the order of 4,700 cm²/g versus about 3,800 cm²/g for a regular Type I cement. No two PLCs are the same, as they are designed to perform similarly to the Type I cements from which they are derived. There is just as much difference between two PLCs as there is between two Type I cements.

How does Limestone work?

- Particle packing: improved particle size distribution as the finer limestone particles fill in between the larger cement grains
- Nucleation surfaces for precipitation: higher surface area of fine limestone provides more area for calcium silicate hydrate (CSH) to form and grow
- Chemical reactions: some contribution

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Industry Standards

The two primary standards for cementitious materials are:

- ASTM C150 Standard Specification for Portland Cement – includes Types I and I/II, II, III, and V
- ASTM C595 Standard Specification for Blended Hydraulic Cements – governs cement Types IP, IS, IL, and IT; allows for pozzolans, slag cement, and limestone

While many U.S. state departments of transportation (DOTs) permit Type IL cements in their construction projects under ASTM C595, for others, AASHTO M 240 Type IL is the proper specification reference. (All of the technical requirements of ASTM C595 and AASHTO M 240 are the same.)

Type IL is also permitted:

By codes, like ACI 318, Building Code Requirements for Structural Concrete

- By specifications, like ACI 301, Specification for Structural Concrete
- By standards, like ASTM C94, Specification for Ready Mixed Concrete
- And by the AIA MasterSpec that is used by design firms to develop their specifications for private projects.

World Wide Acceptance

The U.S. is playing catch-up with PLC. In Europe its usage dates back to the 1960s. Cembureau, the European Cement Association, reported usage of around 30% in 2004. More recently in 2020, the VDZ, the German Cement Association, reported a similar figure domestically with the proportion of blended cement shipments at 32%.

1965
Germany allows cement with 20% limestone to be used for specialty applications

1979
French cement standards allow limestone additions

1983
Canadian portland cement standard allows up to 5% limestone

1990
Blended cements with up to 20% limestone are routinely used

1992
UK cement specifications allow up to 20% limestone

2004
ASTM C150 allows 5% limestone in Types I-V

2008
In Canada, PLC is no longer categorized as a blended cement and is added to the portland cement standard

2012
Blended cement specifications AASHTO M 240 and ASTM C595 were updated, including a definition for PLCs containing between 5% and 15% finely ground limestone as an ingredient

Acceptance of PLC in AASHTO and ASTM standards led to more DOTs adopting PLC and a dramatic increase in production and sales volumes. PLC production growth nearly doubled between 2012 and 2016. PLC is the most rapidly growing blended cement in the market.

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Mix Designs with PLC or Added Fillers

As with any new material, some testing is warranted to confirm the effect of PLC on fresh and hardened properties of concrete (air content, slump, bleed potential, setting time, compressive strength). Typically, the addition of PLC requires little or no adjustment to concrete mixture designs to achieve the same strength, durability, and resilience as mixtures with the same amounts of ordinary portland cement (OPC). In regard to concrete proportioning, batching, and mixing, PLC replaces OPC at a 1:1 ratio. PLC allows for the same dosages of fly ash or other pozzolans, such as slag cement. Some producers report no adjustments are needed, others tweak proportions or adjust admixture dosages.

Adding PLC to a concrete mix design has demonstrated some synergies that could allow more supplementary cementitious materials to be added without set delays, depending on the fineness of the added filler.

Typical Effects on Fresh and Hardened Properties

Workability:	In general, the fineness of the limestone is the main factor that influences workability. The use of limestone may alter the water demand, resulting in a slight increase or decrease of workability when portland-limestone cements are compared to conventional cements.
Bleeding:	Decreases with increasing fineness; generally of no concern.
Initial & Final Setting Time:	There can be slight decrease in setting time with increasing fineness; not a concern even up to 15% limestone content.
Heat of hydration:	Slight increase at early ages (up to 48 hours), but less significant at later ages.
Compressive strength	Can increase slightly, both at early-age and long-term.
Scaling and freeze-thaw resistance:	Use the same mitigation techniques as OPC concrete: proper air-void systems, curing, and high strength mix designs.
Sulfate resistance:	Again, use the same techniques as with OPC concrete mixes: Low water-to-cement ratio, high strength mix designs.