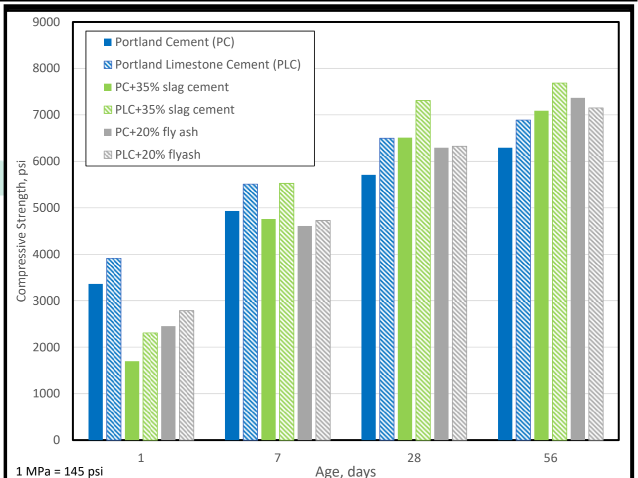
Concrete in Practice
What, why & how?
NRMCA

CIP 45 - Portland-Limestone Cement (PLC)



Concrete Strength made with PC and PLC, Ref. 8

WHAT is Portland-Limestone Cement (PLC)

Portland-limestone cement (PLC) is made with the same ingredients, processes, and equipment as portland cement. PLC is permitted to contain between 5 and 15 percent limestone by specification, while portland cement is permitted to contain up to 5% limestone. PLC can be engineered to provide equivalent performance in concrete to that provided by portland cement from the same source. Replacing portland cement with a PLC reduces the carbon dioxide (CO_2) footprint of concrete by approximately 10% without modifying fresh and hardened concrete properties. Using PLC is an important option for projects with a goal to reduce the carbon footprint of concrete and the built environment and to ensure that concrete construction is competitive on performance, constructability, and sustainability with other building materials.

PLC is typically manufactured to achieve equivalence to portland cement; ready mixed concrete producers can replace portland cement with PLC on a 1:1 basis in concrete mixtures and continue to use the types and quantities of supplementary cementitious materials, admixtures, and other concrete materials without significant changes to established concrete mixtures with historical performance characteristics. Ready mixed concrete producers can continue to operate using well-established systems with a minimal amount of disruption. For most mixtures, concrete properties are unchanged by the use of PLC, although some adjustments of mixture proportions or admixtures may be necessary as would be typical with changing cement sources. The limestone in PLC is not a supplementary cementitious material (SCM) and should not be included in limits on SCMs in specifications or used to offset SCMs required for improved durability.

For contractors and other installers, the handling, placement, and finishing procedures for concrete made with PLC is similar and the same equipment and techniques can be used. This is true for all types of placement methods and different types of construction projects from high-rise buildings, floors, pavements, and other concrete applications. Characteristics of fresh concrete such as slump retention, setting time, bleeding, pumpability, workability, and finishability can be expected to be the same.

The use of PLC in a wide range of exposure conditions has been thoroughly investigated to confirm that PLC can be used to produce concrete of the required strength and durability. This has been evaluated through laboratory testing and long-term field performance in actual projects. Concrete made with PLC has been demonstrated to show resistance to deicer scaling, freezing and thawing, penetration of chlorides, sulfate attack, abrasion, alkali-silica reaction and other severe exposure when the appropriate measures are used.

In the US, concrete with PLC has an established track record for pavements since about 2007. PLC concrete is as equally suited to commercial work as it is to residential applications. It has been used in structural members for buildings, bridges, or other infrastructure, for cast-in-place and precast applications. The use of limestone as an ingredient in cement is not new. It has been permitted in standards globally and used in concrete construction for more than 50 years.

WHY Should PLC be Considered

In response to climate change, there are several national, local, and owner initiatives or codes to reduce the environmental impact of construction. Some groups have established an aggressive CO_2 reduction timeline. All products used in construction have an environmental impact associated with extraction, manufacture, and transportation. One of the factors quantified is the emission of carbon dioxide (CO_2) associated with a manufactured product. CO_2 is one of the emitted gases that contributes to global warming. The contribution of all products used on a project add up to the *embodied carbon* of a constructed structure. While concrete, compared to most construction products, has a relatively low embodied carbon per unit volume, the large volume used globally makes its total embodied carbon content significant. This also offers opportunities for impactful reduction. Concrete is used in all construction projects. Concrete producers are increasingly responding to requirements to document the environmental impact factors of concrete mixtures and to meet reduced targets while maintaining the concrete properties required for construction and design.

Cement is an important ingredient in concrete. Its manufacture involves heating materials to high temperature in a kiln to produce clinker that is then interground with other materials. Limestone, composed of calcium carbonate, constitutes about 60% of the raw materials used in cement manufacture. The burning of fuel to achieve kiln temperature and calcination of limestone result in the emission of CO_2. One method of reducing the embodied carbon of cement is to reduce the clinker content in the finished product. Since the 1970s, improvements to U.S. cement manufacturing have resulted in a more than 40% decrease in energy usage, which reduces embodied CO_2. As optimizations to manufacturing technology level off, reducing the clinker factor in cement and concrete is the primary option to reduce embodied carbon. PLC offers an opportunity for cement manufacturers and ready mixed producers to continue the reduction of embodied carbon in cement and concrete.

While cement is approximately 10 percent of the volume of a concrete mixture, it contributes to a large portion of the embodied carbon of the mixture. Producers have several options to optimize concrete mixtures for required performance through the judicious use of supplementary cementitious materials, chemical admixtures, recycled materials, and mixture proportioning concepts. As indicated earlier, using PLC is a relatively easy switch to achieve an additional 10 percent reduction in embodied carbon without compromising concrete performance. Performance-based specifications that do not dictate or restrict composition of concrete mixtures are important for producers to achieve reduced embodied carbon goals.

HOW Can PLC be Permitted

Portland-limestone cement (PLC) is designated as Type IL(X) in ASTM C595, *Specification for Blended Hydraulic Cement*, where "X" indicates the limestone content in the blended cement. Many state highway agencies use the equivalent AASHTO M 240. In Canada, the applicable specification is CSA A3000. Blended cements meeting ASTM C595 may also include limestone and other SCMs, designated as Type IT, and can also be manufactured to comply with ASTM C1157, *Performance Specification for Hydraulic Cement.* Industry standards including ACI 318, *Building Code Requirements for Structural Concrete*, ACI 301, Specification for Structural Concrete, ASTM C94, *Specification for Ready-Mixed Concrete*, AIA MasterSpec, and the United Facilities Guide Specification used by the Department of Defense include references to ASTM C595 and C1157, thereby permitting the use of PLC. There are no conditions that restrict the use of PLC. These concrete industry standards are referenced in the International Building Code and International Residential Code that are adopted by local jurisdictions. Most of the state highway agencies in the US permit the use of PLC by including a reference to ASTM C595 or AASHTO M 240 in their construction specifications. PLC is permitted for construction of airfields, federal buildings, and infrastructure.

The use of PLC can be permitted by including a reference to ASTM C595 and ASTM C1157 in specifications for concrete. If these are not referenced, it should be addressed with the engineer of record early in the project bid process. Besides PLC, a ready mixed concrete producer can also choose to use other available blended cements addressed in these specifications, which also help reduce the embodied carbon of concrete.

Projects with a sustainability goal should clearly state these goals to project stakeholders. Mandates on use of specific products or prescriptive limits on the quantities of materials in concrete mixtures are not encouraged. Supply and production constraints are aspects the concrete producer must contend with when choosing the best available option to producing concrete mixtures with reduced environmental impact. CO_2 footprint limits for specific concrete mixtures based on design strength should be avoided. A CO_2 footprint goal for all concrete on a project is a preferred option as it permits tradeoffs between the different mixtures to satisfy design and constructability requirements. A lack of familiarity with PLCs is a most likely reason for these products not being permitted in specifications. Raising awareness of PLC, correcting incorrect perceptions, and explaining the benefits provided is important to advance sustainable concrete construction.

References

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