Concrete in Practice
What, why & how?
NRMCA

CIP 45 - Portland-Limestone Cement (PLC)

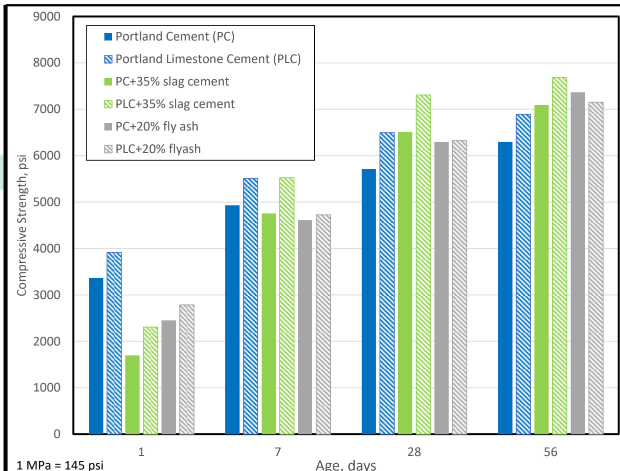
WHAT is Portland-Limestone Cement (PLC)

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. PLC is made with the same ingredients, processes, and equipment as portland cement (PC). ASTM C595 permits PLC to contain between 5 and 15% limestone, while PC is permitted to contain up to 5%. PLC can be manufactured to provide generally equivalent performance to that of PC from the same source. Used at the same content as PC in concrete, PLC reduces the embodied carbon dioxide (CO_2) of the mixture by up to 10%. Using PLC is an important option to reduce the embodied carbon of concrete and the built environment to ensure that concrete construction is competitive.

PLC is typically manufactured to achieve equivalent performance to PC. Limestone, being a softer material, grinds preferentially finer than cement clinker. To achieve a similar fineness of clinker or similar strength, PLC is ground finer than PC from the same source. Finely ground limestone has been shown to be beneficial due to improved particle packing, provide nucleation sites for cement hydration, and formation of additional reaction products, especially when used with coal ash and slag cement, to contribute to workability and strength.

As with the use of any new material, ready mixed concrete producers evaluate the impact of replacing PC with PLC in their mixtures to achieve required performance of fresh and hardened concrete for projects and different applications. Concrete producers can continue to use the types and quantities of supplementary cementitious materials (SCMs), admixtures, and other concrete materials. Legacy concrete mixtures may need some modifications to achieve required performance. The limestone in PLC is not a SCM and should not be included in limits on SCMs in specifications or used to offset SCMs required for improved durability. Limestone is part of the blended cement and is not excluded when calculating the water-cementitious materials (w/cm) ratio of concrete.

For contractors and other installers, the handling, placement, and finishing procedures for concrete made with PLC is generally similar and the same equipment and techniques can be used. Because of increased cement fineness, there may be modest changes to characteristics of fresh concrete such as slump retention, setting time, bleeding, pumpability, workability, and finishability. Some of these factors may impact the timing of finishing operations for pavements and slabs.



Concrete Strength made with PC and PLC, Ref. 9

The use of PLC in a wide range of exposure conditions has been investigated to confirm that PLC can be used to produce concrete of the required strength and durability. This has been evaluated through laboratory testing, field exposure sites, and performance in 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 conditions.

Limestone as an ingredient in cement at varying amounts has been permitted in global standards for more than 50 years. PLC has been used in the US and Canada since the early 2000s. It has been used in structural members for buildings, bridges, or other infrastructure, for cast-in-place and precast applications.

WHY Should PLC be Considered

Carbon dioxide (CO_2) is one of the emitted gases that contributes to global warming. All products used in construction have an environmental impact associated with extraction, manufacture, and transportation. 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. The concrete industry is working to reduce the embodied carbon of its products and have established aggressive targets to a timeline. As required for project’s reduced targets, concrete producers document the environmental impact factors of concrete mixtures while maintaining the concrete properties required for construction and design.

Clinker is the primary material governing the properties of cement. Its manufacture involves heating materials to high temperature in a kiln. Limestone, composed primarily of calcium carbonate, constitutes about 60% of the raw materials used in production of clinker. Burning of fuel to achieve kiln temperature and calcination of limestone result in the emission of CO_2. Clinker is interground with gypsum, limestone and other processing additions to produce cement. 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 one of the options to reduce embodied carbon. PLC offers an opportunity for cement manufacturers and ready mixed producers to make progress towards reducing the 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 concrete. Concrete producers have several options to optimize concrete mixtures to reduce the embodied carbon while achieving required performance through the use of SCMs, chemical admixtures, recycled materials, and mixture proportioning concepts. Using PLC is an important option that can achieve up to 10 percent reduction in embodied carbon relatively easily 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

Type IL cement (PLC) is manufactured to conform to ASTM C595 and AASHTO M 240—*Specification for Blended Hydraulic Cement.* In Canada, the applicable specification is CSA A3001, *Cementitious Materials for Use in Concrete*. Blended cements meeting ASTM C595 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.

In specifications for concrete, the use of PLC can be permitted by including cementitious materials that conform to ASTM C595 and ASTM C1157. If these standards are not included, 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 that conform to these specifications, which also help reduce the embodied carbon of concrete. Specifications should also permit the use of SCMs, such as coal ash, natural pozzolans, slag cement, ground glass pozzolans, that are added at the batch plant when producing 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. Limits on embodied carbon for specific concrete mixtures based on design strength should be avoided. A total limit on embodied carbon for all concrete on a project is a preferred approach as it permits tradeoffs between the different mixtures to satisfy design and constructability requirements. A lack of familiarity with PLCs is a likely reason for not permitting these products in specifications. Raising awareness of PLC, correcting perceptions, and explaining the benefits provided is important to advance sustainable concrete construction.

References

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