CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6858: Evaluating Limestone Cements Containing >15% Limestone

Background

There have been significant efforts worldwide to curb CO2 emissions from cement plants and reduce the overall carbon footprint of concrete products, including the use of alternate fuels in cement plants and the use of supplementary cementitious materials (SCMs) as a partial replacement for cement in concrete. Another effective approach to reduce the carbon footprint of cement and concrete, only recently been introduced in the United States, is the production of portland limestone cements (PLCs), which include the intergrinding of limestone powder with clinker and gypsum. Using uncalcined limestone has the direct effect of reducing CO2 in proportion with the percentage replacement of clinker, and for cement producers, limestone powder is readily available at the plant or nearby.

What the Researchers Did

The research described in this report focused on PLCs with higher limestone contents (e.g., greater than 15%), particularly in paving applications. This comprehensive project included the full-scale production of seven different cements at two Texas cement plants, with limestone contents as high as 30%. These cements were then evaluated in the laboratory and at outdoor exposure sites, allowing the CTR team to study a wide range of fresh, hardened, and durability properties of PLC concrete, including select mixtures in combination with SCMs with limestone contents of up to 30%.

What They Found

Some of the main findings from this 44-month study include the following:

- Similar compressive strengths to ordinary portland cement (OPC) concrete are possible at limestone contents higher than 15%, provided that the cement is ground finer. Lowering the w/cm ratio and/or the use of water-reducing admixtures may be necessary, depending on the actual limestone content. These options may reduce the environmental benefits, but the net environmental benefit is still positive.
- Good quality, low permeability concrete can be obtained by combining SCMs with high limestone PLCs. Depending on the severity of the environment and the exact application, additional measures may be required, such as increasing the concrete cover of steel reinforcement.
- The addition of limestone promotes the hydration of these carboaluminates:
  - —Monocarboaluminate
  - —Hemicarboaluminate
  - —Carbonated hemicarboaluminate
- The addition of limestone results in concrete that is more volumetrically stable than OPC due to the following reasons:
  - —Stabilization of ettringite and subsequent

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formation of carboaluminates, instead of formation of monosulfoaluminate.

—Decreased drying shrinkage due to lower volume of hydrated cement paste.

- The corrosion potential of concrete seems to increase as the limestone content increases. Special attention should be paid to applications where severe exposure to chlorides is typical. The incorporation of SCMs should be strongly considered.
- PLC concrete has significantly lower carbonation resistance when compared to OPC concrete at an equivalent w/cm ratio. For applications where carbonation-induced corrosion is a concern, lowering the w/cm ratio and increasing curing time should be done to minimize the permeability of the concrete. The addition of SCMs will only exacerbate carbonation and special care must be exercised.
- The sulfate resistance of PLC-SCM blends was shown to be strongly affected by the type of aluminate phases present in the hydrated system. In this regard, the stabilization of ettringite and carbonate-AFm phases over monosulfate and less stable calcium aluminate hydrates significantly increased the stability of the mixtures upon exposure to the external sulfates.
- Not only has the present work shown that previously published results can be extended to systems with higher limestone contents, but it has also demonstrated that the performance of commercially available PLC-SCM blends can be significantly enhanced by adjusting the SO3/Al2O3 and CO2/Al2O3 molar bulk ratios through proper selection of limestone, sulfate, and lower-than-thought SCM levels.

What This Means

PLC use will continue in the future. This study showed that constructible, durable, and sustainable concrete can be produced using PLCs with interground limestone contents as high as 30%. However, a detailed understanding of the interactions between portland cement clinker, gypsum, and limestone is needed to ensure that the desired properties can be obtained. To advance the state of the art and current practice with regard to PLCs, implementation projects using PLCs similar to those used in this study with the highest limestone contents should be pursued, starting with a pavement application, preferably a continuously reinforced concrete pavement project. Such real-world data, coupled with the comprehensive database (lab and exposure site) generated under this project, should help to ultimately develop PLC mixtures optimized for a range of transportation infrastructure applications.

For More Information

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