ABSTRACT

Barrett, Timothy J. M.S.C.E., Purdue University, August 2013. Performance of Portland Limestone Cements: Cements Designed to be More Sustainable that Include up to 15% Limestone Addition. Major Professor: W. Jason Weiss.

In 2009, ASTM and AASHTO permitted the use of up to 5% interground limestone in ordinary portland cement (OPC) as a part of a change to ASTM C150/AASHTO M85. When this work was initiated a new proposal was being discussed that would enable up to 15% interground limestone cement to be considered in ASTM C595/AASHTO M234. This work served to provide rapid feedback to the state department of transportation and concrete industry for use in discussions regarding these specifications.

The proposal for increasing the volume of limestone that would be permitted to be interground in cement is designed to enable more sustainable construction, which may significantly reduce the CO_2 that is embodied in the built infrastructure while also extending the life of cement quarries. Research regarding the performance of cements with interground limestone has been conducted by the cement industry since these cements became widely used in Europe over three decades ago, however this work focuses on North American portland limestone cements (PLCs) which are specifically designed to be achieve similar performance as the OPCs they replace.

This thesis presents a two-phase study in which the potential for application of cements containing limestone was assessed. The first phase of this study utilized a fundamental approach to determine whether cement with up to 15% of interground or blended limestone can be used as a direct substitute to ordinary portland cement. The second phase of the study assessed the concern of early age shrinkage and cracking potential when using PLCs, as these cements are typically ground finer than their OPC counterparts.

For the first phase of the study, three commercially produced PLCs were obtained and compared to three commercially produced OPCs made from the same clinker. An additional cement was tested where the limestone was blended (i.e., not interground) as needed, enabling better control of the size and content of limestone. In addition, one of the commercially produced cements was used with fly ash. A series of standardized tests were run to assess the physical effects of intergrinding limestone in portland cement, the effect of limestone presence and method of inclusion on the hydration reaction, and the associated mechanical and transport properties of concretes made with these limestone cements.

The second phase of the study used a commercially produced OPC, a PLC, and a PLC-slag all made from the same parent clinker to assess the potential for early age shrinkage and cracking potential. The study presents a series of tests that quantify the fundamental origins of shrinkage in cementitious materials to elucidate the differences between PLC and OPC. The bulk shrinkage of these systems is then quantified under free and restrained conditions to provide an assessment of the susceptibility of cracking in portland limestone cements.

The results of the first phase of this thesis showed that in general the PLC and OPC systems have similar hydration, set, and mechanical performance. Transport properties in this study show behavior that is +/- 30% of the conventional OPC system depending on the system. Literature has shown similar freeze-thaw resistance when these materials are used in properly air entrained mixtures, and the results for PLC systems with fly ash show added performance. Based on these results it appears that PLC that meets ASTM C595/AASHTO M234 should be able to be used interchangeably with OPC, while it should also be noted that the investigation of the influence of salts and sulfates on PLCs is still ongoing.

The results of the second phase of this thesis showed that while the PLCs are finer, this comes primarily by reducing the very large particles (clinker particles greater than 30 microns) and increasing the number of fine limestone particles. This results in the cements tested having similar autogenous shrinkage development in the PLC systems compared to the OPC, with slightly less shrinkage in the PLC-slag system. The stress that develops when this shrinkage is restrained is very similar in comparing the OPC, PLC and PLC-slag systems and the PLC mixture tends to crack at a similar or slightly earlier times.