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Cement & Concrete Composites

Editorial

The previous issue of this Journal was devoted to Portland Limestone Cements. A problem associated with the use of limestone coarse and fine aggregates in portland cement concretes is the particular form of potentially serious lack of durability arising from the formation of Thaumasite. There have been few reports on the formation of Thaumasite compared with ettringite and gypsum as a result of sulfate attack, but this may largely be due to the very similar crystal structures of ettringite and Thaumasite, and they could be easily confused. Buried concrete structures are especially at risk of the Thaumasite form of sulfate attack as the major risk factors associated with this are low temperatures of 5 to 10°C, the presence of water, adequate supplies of calcium silicate, sulfate and carbonate, and reactive alumina.

The addition of fillers or "adulterants" to cements dates back to the late nineteenth century. Fillers were generally considered to be non-hydraulic, and it had been widely assumed that they do not react with the cement, water or aggregate in the mortar or concrete. Ground limestone and slags were generally used as the adulterants, with a view to reducing manufacturing costs, without a clear understanding if they were truly inert or not. It was not until the 1970s that filler cements came to be accepted, as demands for more energy efficient manufacturing processes increased. In France, for example, portland limestone cements have been manufactured since 1976, as composite portland cement, although crushed sand or crushed limestone were not strictly allowed as partial replacement of cement clinker.

The term filler is generally applied to replacements of up to 5% of inorganic mineral materials, which can have "inert or slightly hydraulic, latent hydraulic or pozzolauic properties". The New European Standard DD ENV 197 allows the addition of up to 35% by mass of limestone in certain classes of composite cement. In the UK, the addition of finely divided limestone to portland limestone cements is restricted to a maximum of 20%, and such cements are recommended for use only in Class 1 sulfate conditions in accordance with the BRE Digest 363. In France, on the other hand, there existed in 1990 sixty seven brands of composite cements, of which sixty one contained limestone as a filler, whilst twenty nine of them had filler contents of 15 to 25%.

It is now well known that the addition of ground limestone does affect the properties of the cement, and that the filler is not completely "inert". The effects of carbonate additions to portland cement are however, not completely understood, and there are many conflicting views concerning their contribution to strength development and durability, and indeed of the general suitability of portland limestone cements in all conditions of exposure. More recently, as referred to earlier, concerns have centered on the formation of Thaumasite, a product of sulfate attack, which has been identified in the foundations of many concrete structures containing limestone fines and/or limestone coarse aggregates.

Recent research now shows that portland limestone cement pastes are susceptible to the Thaumasite form of sulfate attack at 5°C after only a few months exposure to sulfate solutions. The extent of such thaumasite formation is greater with increasing limestone additions. This type of attack is particularly deleterious when magnesium ions are also present. Then Thaumasite formation is accompanied by formation of brucite and secondary gypsum. There is always a delay before Thaumasite is formed. During this initial period the usual cement hydration reactions take place, leading to the formation of ettringite, C—S—H gel and portlandite. Reduction in the pH of the system may be important in that it results in chemical attack of the C—S—H gel.

These studies also show unambiguously that mortar and concrete specimens containing 35% limestone content and exposed to sulfate attack at 5°C will suffer serious material and structural damage. The progression of such damage can be very rapid and quick with the occurrence of serious damage very suddenly without much warning. There is also strong evidence that even the 15% limestone content level could be at risk of serious sulfate attack if the exposure to environment is long-term.

As pointed out in the past in these columns, whatever be the nature and form of these damage processes, en-

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gineers should not allow themselves to be overwhelmed or blinded by field occurrences of such damage. There are clear and positive directions in which such damage processes can be overcome, and protected against. But the essential need is to have a clear understanding of the causes and mechanisms of such deterioration processes, and this alone can lead to durable and cost-effective solutions.