GUIDELINE FOR THE CONTENT OF SULPHATES IN CONCRETES & MORTARS.

Introduction

Normal Portland cement contains between 2.5 and 3.5%$^{w}/_{w}$ sulphate. When Portland cement is used to prepare concrete, in the normal cement/sand ratios, the maximum amount of sulphate expected in the concrete is <1%$^{w}/_{w}$. Any chemical sulphate result above this level should be investigated.

This guidance note is designed to assist in the interpretation of chemical sulphate results; it is not designed to provide absolute advice, as each individual case must be independently evaluated with respect to other construction criteria and ‘best practice’, etc. In this respect Waterfall & O’Brien cannot be held responsible for individual decisions and judgements based on the information provided in this guidance document.

Scope

This guidance note is only applicable to concretes and mortars made with Portland cement, or pre-cast concrete structures prepared using Portland cement (e.g. Reinforced Autoclaved Aerated Concrete planks, etc). These guidance notes are not intended to be used for lime-based mortars and screeds that do not contain cement based products.

Guidelines

Portland cement is a finely-ground powder produced by grinding Portland cement clinker with gypsum and other minor constituents as allowed by various standards. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element.

THE CHEMISTRY OF CEMENT BONDING.

When water is mixed with Portland cement, the product sets in a few hours and hardens over a period of weeks. The initial setting is caused by a reaction between the water, gypsum, and tricalcium aluminate, forming the crystalline hydration products calcium-alumino-hydrate, ettringite, and monosulphate. The later hardening and the development of cohesive strength is due to the reaction of water and tricalcium silicate, forming an amorphous hydrated product called calcium-silicate-hydrate gel. In each case the hydration products surround and cement together the individual grains. The hydration of dicalcium silicate proceeds more slowly than that of the above compounds slowly increasing later-age strength.

STANDARDS AND TYPES OF CEMENT.

There are different standards for classification of Portland cement. The two major standards are the ASTM C150 used primarily in the U.S. and European EN-197. The cement types are given in table 1.

Table 1: EN 197-1 defines 5 classes of common cement that comprise Portland cement as a main constituent. These classes differ from ASTM.

I	Portland cement	Comprising Portland cement and up to 5% of minor additional constituents
II	Portland-composite cement	Portland cement and up to 35% of other single constituents
III	Blastfurnace cement	Portland cement and higher percentages of blastfurnace slag
IV	Pozzolanic cement	Portland cement and up to 55% of pozzolanic constituents
V	Composite cement	Portland cement, blastfurnace slag and pozzolana or fly ash

Constituents that are permitted in Portland-composite cements are blastfurnace slag, silica fume, natural and industrial pozzolans, silicious and calcareous fly ash, burnt shale and limestone.

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GENERAL PHYSICO-CHEMICAL PROPERTIES OF SULPHATE ATTACK.

The exposure of concretes and mortars made with Portland cement to sulphate salts can cause damage due to an expansive reaction between the Tricalcium Aluminate phase of the cement and the sulphate salt to form crystals of Ettringite. Given adequate space to form, the Ettringite forms needle like crystals, but in confined space causes an expansive reaction as the amorphous product develops. This initially leads to crumbling, expansion and cracking of the mortar, but in the worst cases can result in the expansion of masonry causing severe disruption. This is called 'Delayed Ettringite Formation' (DEF).

As specified earlier, Portland cement contains gypsum (calcium sulphate at a maximum of 5%), and on the addition of water forms, among other things 'ettringite'. The gypsum is added to cement to control setting times and is not the cause of failure due to sulphate attack, as the reaction is completed during the preparation and setting of the concrete and mortar.

SULPHATE ATTACK

For Sulphate attack to occur all five of the following are needed;

1. Presence of sulphate salts,
2. Tricalcium Aluminate content of cement greater than 8%,
3. Permeable mortar,
4. Mortar remains wet for prolonged periods,
5. Water travels from the sulphate source to the mortar.

If any one of these factors is absent, there is no potential for sulphate attack to take place.

True sulphate attack is relatively rare, and research work suggests that concrete made with a reasonable cement content (at least 330KgM3) and a reasonably low water/cement ratio is attacked only slowly. The rate of damage is also dependent on the rate of replenishment of the sulphate salts. The availability of soluble sulphate salts can arise due to the type of bricks used, from ground water, as a result of airborne pollution or due to contamination with de-icing products

THAUMASITE FORM OF SULPHATE ATTACK (TSA)

Normal sulphate attack usually results in the formation of ettringite. This uses aluminium provided by the cement and clearly this is limited in quantity in normal concrete. However, thaumasite formation does not involve aluminium; given an adequate supply of sulphate and carbonate, thaumasite can continue to form until the calcium silicate hydrate is completely decomposed. Consequently, while the use of sulphate-resisting Portland cement provides some defence against normal sulphate attack, it does not give any particular protection against thaumasite formation. Sulphate can be supplied from a range of sources; groundwater or bricks are common examples. Carbonate can be supplied from atmospheric CO_2 or from limestone present in the concrete or mortar.

TREATMENT METHODS

Any assessment of a structures 'fitness for purpose' should be based on the physical observations made on-site, backed up by the chemical testing results if possible. There is no treatment for obvious sulphate attack except to repair the affected areas, remove or protect the structure from the sources of sulphate salts, and protect the area from water ingress and keep the area dry if possible.

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