Petrographic examination of hardened concrete is a quick and well suited method of diagnosing reasons for lack of concrete durability and of doing quality control of new concrete structures. This paper describes the technique, which is now widespread in Denmark, and discusses the information obtained by the method, a lot of which cannot be obtained in any other way.

1. Introduction

The increasing number of damages on concrete structures, which has been reported from almost all over the world within the last 10 - 15 years, has created a need for the development of techniques to reveal the cause of the damages and to evaluate the present quality of concrete structures.

Furthermore it has become clear that it is necessary to increase the specifications and to carefully control that the specifications are fulfilled in future concrete structures.

Petrographic examination of hardened concrete is a quick and well suited method of diagnosing concrete problems and of doing quality control of new concrete.

Petrographic examination of hardened concrete yields information of all phases the concrete has gone through:

- what type of materials has been used and in what amounts.
- the quality of the working methods used: mixing, compaction, curing etc.
- secondary reactions disintegrating the concrete.

The technique has now been used for some years in Denmark for damage analysis and for quality control and petrographic examination is now specified for quality control of Government subsidized building.

2. Description

Petrographic examination should include macro analysis, micro analysis and perhaps air-void analysis (1, 2, 3). The examination most often is performed on a core drilled from the structure or from test castings.

2.1. Macro analysis

The macro analysis is a visual inspection of the concrete core sawn longitudinally.

The result of this analysis is first of all an impression of the homogeneity of the concrete and secondly informations on the concrete constituents. In some cases indications of secondary reactions are obtained as well.

In case of quality control there is no point in doing further analyses if the concrete turns out to be very inhomogeneous, e.g. by segregation (Fig. 1). In such cases the concrete will be rejected anyhow.

2.2. Micro analysis.

The micro analysis is performed on thin sections, a 20 micron thin section of the concrete glued on to a glass plate and covered by a cover glass. The area normally is 30 × 50 mm.

The thin section is prepared by grinding an epoxy impregnated piece of concrete to the proper thickness.
Fig. 1. Concrete core showing severe segregation (see sec. 3.2). Length of core: 20 cm.

20 microns. Before impregnation, which is done under vacuum, a fluorescent dye is dissolved in the epoxy. The epoxy penetrates the voids in the concrete, the capillary voids, the air-voids and the cracks.

The thin section is examined using a polarizing and fluorescence microscope with transmitted light and with magnifications of 25x to 250x.

From this analysis the petrographer obtains detailed information on the concrete constituents, on the working methods used and of secondary reactions that has taken place in the concrete.

Furthermore the homogeneity on a micro-scale and the amount of micro-cracks will be evaluated during this analysis.

2.3. Air-void analysis

This analysis is performed either on contrast impregnated polished sections, 10 × 10 cm, or on thin sections. The analysis can be done manually by point-counting or automatically using an image analyser.

The examination gives information about the total air-content and the specific surface of the air-voids (2).

This type of analysis is primarily used for quality control of new concrete.

3. Discussion

The results obtained from the analysis yields information of all phases the concrete has gone through.

3.1. Concrete constituents

Type and amount of the various concrete constituents is determined during the micro analysis.

Aggregate

Type and amount of the aggregate is determined by mineralogical identification and point-counting.

This determination is especially important, when doing quality control in areas where certain types of aggregate are known to be problematic, e.g. because of alkali reactivity or porosity.

The area of the thin section is too small to evaluate the amount of coarse aggregate. This has to be measured during the macro analysis.

Cement

The unhydrated cement grains are identified by the optical properties of the cement minerals, primarily alite and belite (C3S and C2S resp.) Unhydrated cement is always present in concrete and from this identification the degree of hydration can be estimated.

Type of cement can in some cases be determined from standards and experience.

Due to impregnation of the capillary voids with the fluorescent epoxy, the capillary porosity can be estimated using UV-light. The capillary porosity is a function of the water/cement-ratio (3), and from this, again using standards and experience, the water/cement-ratio can be determined.

The accuracy of this determination is fairly good. In the range of w/c-ratio from 0.35 - 0.55 the determination can be done with an accuracy of 0.05.

Having determined the w/c-ratio and having determined the volume of cement paste (cement + water) by point-counting, the amount of cement (kg/m³) used at the production of the concrete can be calculated (4).

PFA

Puverized fuel ash is readily identified as glassy, isotropic, vesicular and rounded particles. An exact quantification cannot be done because some of the PFA-particles are smaller than the resolution of the microscope, but the amount can be estimated.

Silica fume

Silica fume has become more and more used in the production of concrete within the last few years. The reasons for this is improvement of the physical properties and the durability of the concrete, as well as improvement of the properties of the fresh concrete (5).

These effects are however only achieved if the silica is well dispersed in the cement paste. If, as is often seen, the silica fume is agglomerated in larger balls, with a