QUALITY CONTROL OF SAND BY MEANS OF POINT-COUNTING IN LIGHT-OPTICAL MICROSCOPE

by

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1. INTRODUCTION

The Farø Bridges are two bridges, with a total length of 3.3 km, connecting the islands Zealand and Falster. The bridges are an integral part of the motorway leading from Copenhagen to Rødby. From here ferries are connecting Denmark with West-Germany. The bridges are presently under construction. The total concrete volume to be used is approx. 45,000 m^3, and the specifications include requirements of sand properties which can only be measured by means of petrographical microscope using thin sections. The measurements are carried out as a matter of routine where results are given as early as 4 days after reception of a sample of the sand in the laboratory. The present article describes the techniques and instruments used. The results obtained are included, and the experience is discussed.

2. REQUIREMENTS TO BE MET BY SAND

Among the requirements to be met by the sand used for the concrete of the Farø Bridges is the following:

> "The content of alcali-silica reactive particles, dense and porous flint, opal-sandstone etc. must not exceed 2.0% by weight given as a characteristic value".

The characteristic value is defined as the upper 10% fractile on 75% significance level and 25% producer's risk. It is calculated by using the formula $g + k \cdot s \leq 2.0\%$. The factor k is found in appropriate tables.

The reasons for the requirement are the following: Alcali-silica reactions in the sand-fraction is a major cause of deterioration of Danish concrete constructions /1/.

The reactive particles can be found in all grain-size fractions of the sand, and the reactions have accelerated severely when salt from external sources like road salt used for de-icing purposes has access to the concrete.

The 2% level has been specified because earlier experience has shown that this is a "safe" limit for the content of reactive particles under Danish conditions /2/.

3. TECHNIQUES AND INSTRUMENTATION

The sand used for the concrete is a sea-dredged sand from a local source. The upper grain-size is 2 mm. The sand is delivered in 300 m^3 shiploads. From each shipload 3 samples of approx. 5 kg each are collected during unloading of the ship. The samples are immediately sent to the laboratory. The sand is dried and carefully divided into a sample size of about 200 g, from which approx. 50 g of dry sand is collected. This sample is placed in a suitable plastic container and embedded in an epoxy resin. Ciba-Geigy By 158 hardened with Ciba-Geigy Hy 2996 is used for this purpose. The epoxy is stained yellow adding a flourescent dye-stuff Dayglo D-250, Hudson yellow,

approx. 1.4% by weight. The reason for this is that porous particles in the sand absorb the araldite and can be identified by means of a fluorescent mode of microscopy. The method is somewhat similar to the technique described by Romer /3/.

After embedding, the sample specimen is cut parallel to the casting directions (perpendicular to the surface) to ascertain that separation of the sand, if any, is represented in the final section.

After cutting, a thin-section is prepared in a step-wise process using cutting, grinding, and polishing by means of appropriate diamond tools. The thin sections are about 30x50 mm, approx. 20 μm thick, and are analyzed in an ordinary petrographical microscope.

The microscope used is one of the following:

Leitz Ortoplan, Leitz Ortolux or Leitz SM-lux pol equipped with analyzer and polarizer. The measurement is carried out at 63 x magnification. To measure the content of reactive particles ordinary point-counting is used. The sample is measured in a semi-automatic Swift pointcounter, and 3000 points are counted. Normally this gives about 1900 points recorded as sand particles and 1100 points as embedding epoxy.

The point-counting is an area-measurement, directly proportional to the volume of the components. To calculate the content of alcali-silica reactive particles in percentage by weight, it is necessary to find the density of the particles.

Flint, which is the only particles of interest in the sand, has densities varying from 2.60 g/cc to about 1.80 g/cc. To get information about the density, the porosity of the flint must be known. This is obtained by means of a flourescent mode of microscopy utilizing the fluorescent dye-stuff added to the epoxy resin as well as known standards of porous flint, by comparing the intensity of the yellow light within the particle with the standards. When the volumen and the density are known, the amount in percentage by weight can be calculated.

4. RESULTS

The geology of the sand used is unknown, since geological observations on the bottom of the sea are difficult to obtain. An area has been located, and test-dredging within this area on 11 sample locations have been carried out. The resulting flint contents are found in table 1. The area is identified by means of Decca-coordinates. From this area all shiploads are taken. The ship is unloaded directly at the building site, where a small harbour has been built. It is not permitted to use sand from a given shipload until the flint content is known. The sand has now been tested during a period of about two years. The content of flint has been counted in 162 thin-sections, and no single value has been measured exceeding 1.6% by volume. The results are shown on tabel 2 and illustrated in histogram 1.

Using the formula $g + k \cdot s \leq 2.0\%$, the calculation shows that the requirement is met. Only two shiploads with mean values about 0.5% by weight should have been rejected because the standard deviation was too high. The k-value used for n = 3 is 2.50 and the k-value for $n = \infty$ is 1.28. The k-values are calculated on the assumption that the results are normally distributed which seems to be an applicable assumption, despite the fact that the flint content is close to zero, and a skewed distribution is expected.

Table 1

Sample	Content of flint grains nos.	%
637.1	13	0.72
637.2	8	0.44
637.3	16	0.88
637.4	6	0.33
637.5	10	0.55
637.6	11	0.61
637.7	5	0.27
637.8	16	0.88
637.9	10	0.55
637.10	12	0.66
637.11	14	0.77

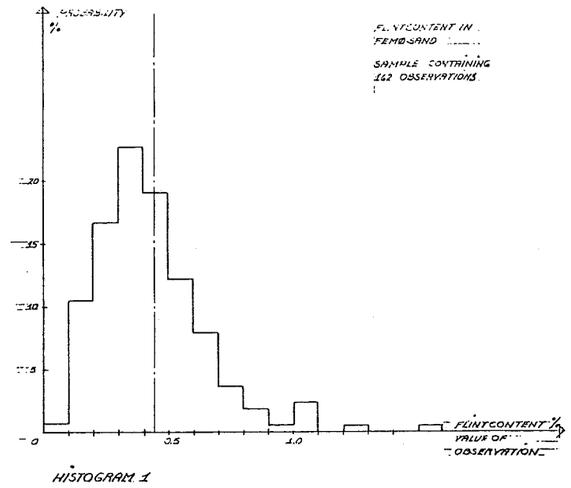
11 values
g = 0,60%
s = 0,20%

Table 2

0,37	0,16	0,34	0,56	0,25	0,31
0,16	0,20	0,67	0,64	0,40	0,45
0,16	0,31	0,43	0,62	0,35	0,43
0,49	0,70	1,59 K	0,46	0,53	0,48
0,33	0,27	0,53	0,63	0,41	0,40
0,27	0,49	0,57	0,44	0,28	0,52
0,53	0,54	0,11	0,17	0,31	0,40
0,11	0,33	0,25	0,28	1,08	0,85
0,65	0,43	0,51	0,27	0,52	1,10
0,17	0,48	0,22	0,27	0,34	0,27
0,51	1,07	0,26	0,45	0,21	0,16
0,38	0,67	0,32	0,16	0,39	0,27
0,35	0,27	0,28	0,32	0,22	0,23
0,51	0,32	0,42	0,28	0,28	0,48
0,52	0,34	0,45	0,40	0,29	0,12
0,78	0,29	0,70	0,37	0,45	0,48
1,28	0,11	0,74	0,39	0,96	0,36
0,05	0,40	0,48	0,11	0,52	1,02
0,54	0,68	0,88	0,16	0,62	0,42
0,42	0,75	0,34	0,31	0,80	0,28
0,84	0,11	0,44	0,45	0,42	0,59
0,39	0,34	0,67	0,34	0,36	0,30
0,62	0,24	0,57	0,44	0,38	0,57
0,77	0,32	0,24	0,35	0,71	0,20
0,40	0,16	0,32	0,54	0,44	0,26
0,34	0,43	0,44	0,54	0,53	0,41
0,56	0,45	0,47	0,23	0,33	0,61

162 values
g = 0,44 %
s = 0,23 %

250.000 grains
1.100 flint grains



HISTOGRAM 1

5. DISCUSSION

Under the appropriate, unfavourable conditions alcali-silica reactions in concrete may cause very severe damage. In fact a large number of structures may be listed which have been damaged to such an extent that total rebuilding has been the only way of repair.

The only way of obtaining total security against the reactions is to avoid the use of reactive aggregates. Various physical methods have been developed to predict the behaviour of a given aggregate exposed to an aggressive environment /4/, /5/, but the physical experiments are pretty time consuming. Even if the reactions are accelerated in a NaCl-saturated water solution at a constant temperature of 50°C /5/, certain reactive sand types requires test periods of about half a year to ascertain absolute certainty /6/. Various chemical methods have also been developed in order to predict the behaviour of the aggregates /7/, /8/ in an alcali-silica aggressive environment. The ASTM-method demonstrates that litterally all Danish aggregates are potentially reactive, but experience shows that this is not true. The German method /8/ only focuses on the fractions above one mm grain size and is only valid for materials in which the reactive agent is found as cement in sandstones. The use of this method on Danish aggregates gives a considerable risk of accepting sand which will be dangerous to use in an aggressive environment. No chemical method exists which is able to distinguish between dangerous and innocent aggregates under all conditions.

Among the methods available to measure the content of alcali-silica reactive particles in concrete aggregates, the optical methods seem most promising. The present experience shows that the measurements can be carried out within four days which is reasonably quick in a quality control situation. Provided the reactive particles can be identified in petrographical microscope, the content is easily measurable with standard techniques like point- counting.

In the present example two major difficulties have had to be overcome until the measurements were meaningful. The two problems were the following:

The requirement is given in statistical terms which implies that the standard deviation is multiplied by a factor exceeding 1.28. This means that a very high degree of precision has to be achieved during the measurement. Among others, two possibilities of acceptance exist when using the formula $g + k \cdot s \leq 2\%$. A low mean value g combined with a comparatively large standard deviation s or a larger mean value together with a comparatively low standard deviation.

The mean value is dependent on the material itself. The standard deviation is to some extent influenced by the way the measurements are carried out. Since the acceptance interval in the present case is only 2.0% wide, a very high degree of precision is necessary. This means that the definition of flint has to be very limiting. Various carbonate-carrying, fossiliferous or calcedony-carrying types of flints are easily recognizable, but homogeneous, dense flint, which is a micro-crystalline quartz aggregate, is difficult to distinguish from fine-grained quartzites, supposed to be innocent, at least the type of quartzite found in Danish aggregates. In the fluorescent microscope the quartzite will usually appear slightly weathered and has absorbed a small amount of fluorescent dye-stuff at the grain-boundaries, in which case they can be recognized, since the flint of this particular type is unweathered. If the fluorescence cannot be taken into account, the universal grain-size is measured. If the quartz particles are below 20 μm, the particle is considered to be flint /9/. If the quartz particles are larger than 20 μm, it is considered to be quartzite.

The other difficulty to be taken into consideration is the fact that the specification is given in percentage by weight. Since the point-counting is equivalent to a volume measurement, the density must be measured. This is not possible by any physical method and therefore the previously described technique of fluorescent microscopy had to be further developed. As known for the time being, this is the only way of measuring the density of porous aggregates in a simple fashion on small particles. The same principle is used routinewise to determine the capillary porosity of hardened cement paste, from which the w/c-ratio of hardened concrete can be judged.

When the volume and type of flint is known, the calculation of the percentage by weight is easily done, since the remaining part of the sand is so rich in quartz that a density of 2.65 g/cc is an applicable guess.

An unintentional effect of the specification in percentage by weight is that this allows a higher volume of porous, dangerous flint than of dense, rather innocent flint. This was hardly the intension of the specification authors.

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DETERIORATION OF CONCRETE STRUCTURES IN SOUTH WEST ENGLAND:

THE USE OF CRACK MAPPING AS AN INVESTIGATORY TOOL

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ABSTRACT

For the purpose of mapping deterioriation of concrete, cracks can be classified into two groups; non-progressive and progressive. Each form of deterioration can be characterised by a particular crack pattern and other surface features.

A programme of field investigations was carried out on several structures in south-west England in order to help assess causes and types of cracking, their structural significance and remedial measures. One structure, a multi-storey car park, was chosen for detailed study. The types of crack patterns were diagnosed by mapping and testing selected members in detail. The results were extended to a classification survey of the whole structural frame of the car park which aided the establishment of trends in deterioration. Details are given of how a simple coloured summation map was constructed to highlight areas which were in need of immediate attention. The widespread occurrence of alkali-silica reactivy and reinforcement corrosion was of particular significance.

A classification survey of the other structures, which were made of materials similar to those used for the car park, provided data which was plotted as a graphical relationship between age and condition. From this, a speculative trend envelope for the local rate of deterioration was established for structures with alkali-silica reactivy in south-west England.

FIELD INVESTIGATIONS

CRACK MAPPING

1. INTRODUCTION

1.1. Earlier investigations of concrete structures have generally aimed at collecting information on the durability characteristics and the various types of any deterioration present. Results of investigations have enabled decisions to be made on the needs for maintenance and/or repairs of affected structures. The following list outlines the various procedures that have been applied, in full or part, during many investigations:

(a) Compilation and evaluation of data on initial concrete quality

(b) Visual examination of the field behaviour of the concrete