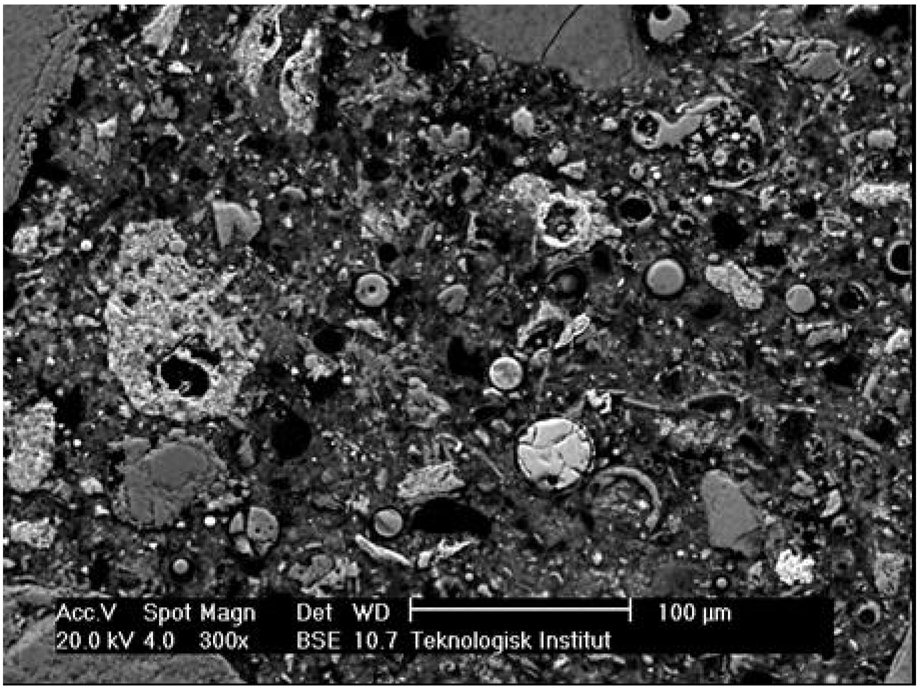
TEKNOLOGISK INSTITUT

BioCrete TASK 7

Bioash in existing concrete structures



Prepared for:
BioCrete

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Building Division

TEKNOLOGISK INSTITUT

Title:	**BioCrete Task 7** **Bioash in existing concrete structures**
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Content

1. Background and scope

The following report is a compilation of the condition survey investigations of bioash concrete from the demonstration highway bridge at Riis Ølholm (TI-rapport 759925) see (Figure 1) and of the water basins at Herlev Station.

1.1 Background

Bioash concrete of the type A3 from the demonstration highway bridge was looked upon in connection with the investigation of all the different concrete types used in the demonstrationn bridge. The bio ash concrete is used for the settling slabs placed in succession of the bridge deck and cast during November 2002. The bioash concrete was proportioned to comply with the requirement for the aggressive environmental class, and contained CEM I (rapidcement) bioash).

Figure 1. Image showing part of the west side of the bridge. On the edge beam is seen a colour difference between two types of concrete. The three columns are cast with different concrete types.

Figure 2. Surface of the settling slab cast using bio ash concrete of the demo bridge. A grid of fine cracks were observed in the surface as well as a few small break-offs at the dilation joint.

The bioash concrete from the water basins at Herlev Station was cast in 2004. The water basins consists of three Ø1600mm corrugated PPE pipes connected at the ends by concrete connections made in conventional gray concrete. The PPE pipes are placed on a deck of conventional gray concrete. Between the pipes and up to final level a bio ash concrete has been used containing CEM I (rapidcement), fly ash and bio ash.

1.2 Scope

The scope of the present report is the summarize the condition of the two investigated bio ash concretes and compare the results to what is normally observed for similar structures made with conventional concrete without bio ash..

2. Summary

2.1 Extent of investigation

The summary is based on the following data:

Structure	*Field investigation*	*Laboratory investigation*
Demo bridge	Yes	”Structure” analysis incl. optical microscopy, chlorid analysis, compressive strength test
Water basin	Not possible	”Structure” analysis incl. optical microscopy and SEM (scanning elektron mikroskop) of beton. Analysis of the bioash in the concrete by optical microscopy and SEM.

2.2 Results

Demo bridge

In general the field inspection revealed no cracks or wear such as tracks from heavy traffic was observed on the bio ash concrete (Figure 2).

Petrographic ”structure” analysis

The petrographic analysis showed that the bioash concrete is in good condition in terms of durability and that no flaws from the casting and curing processes are observed (Figure 3).

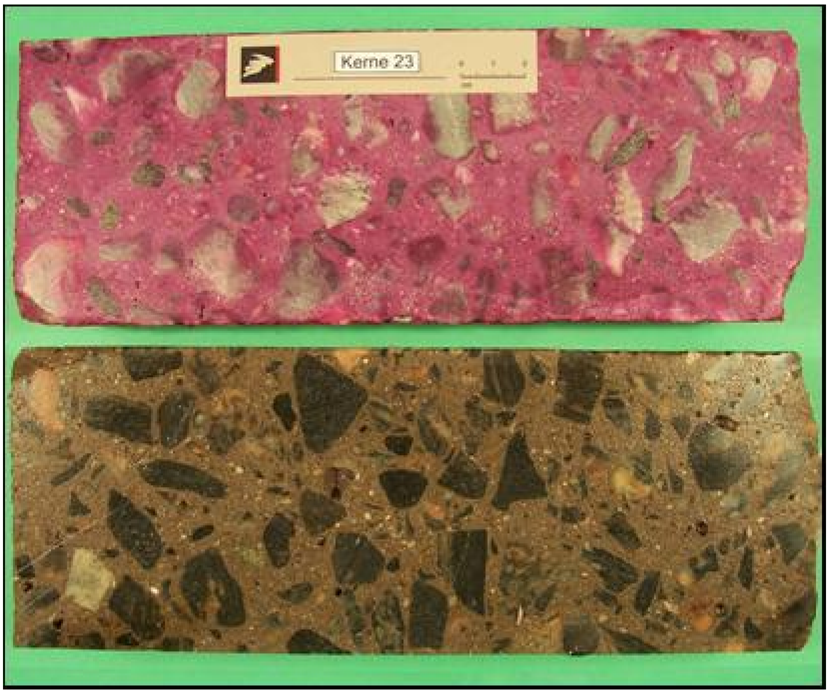

Figure 3. Surface of the concrete to the left. In the top image pH-indicator is sprayed onto the concrete to reveal carbonation. – no carbonation found.

The microscopy analysis showed that there is no difference between the concrete at the surface and in the interior. A few fine cracks are observed at the surface extending to a maximum depth of 6mm (figure 5). I addition some cracks are observed in the paste and some adhesion cracks are found at the interface between paste and aggregate in the interior of the concrete. The observed surface cracks primarily extend through the paste and appear to have formed at a relatively early age. The surface is on the average carbonated to a depth of 3mm, however deeper carbonation is observed along cracks (figure 4). The air content of the concrete is estimated to be around 6 %-vol. The water to cement ratio is estimated to be about 0.40.

In the optical microscope no evidence of reaction of the bioash particles can be found, and investigation of the samples in the SEM did not bring any evidence that reactions involving bioash had taken place.

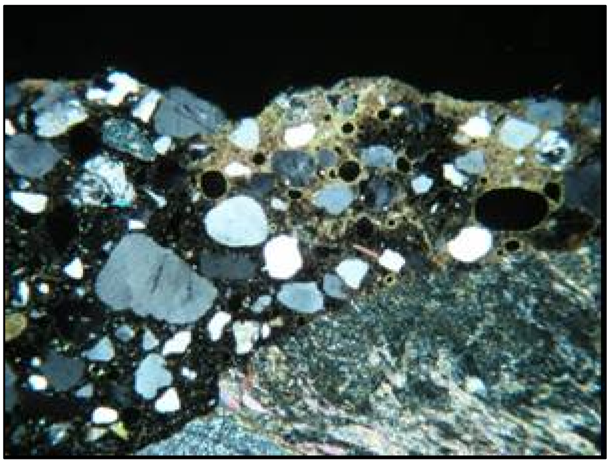

Figure 4. Image showing carbonated pasta (brownish) at the surface of the concrete. Cross-polarized light, field of view 3.8mm x 5.1mm.

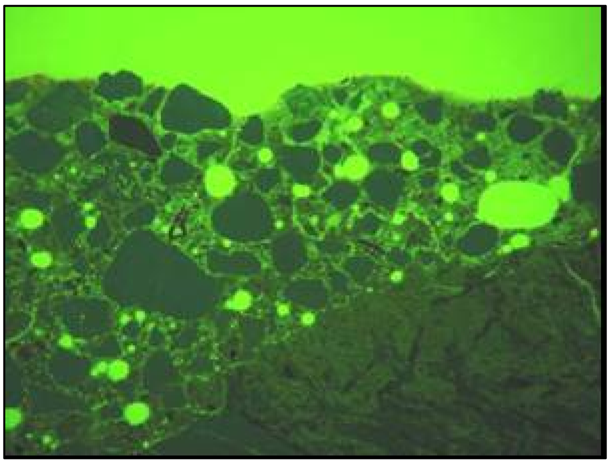

Figure 5. Image showing air void structure, micro cracks and difference in capillary porosity at the concrete surface. Fluorescent light mode, field of view 3.8mm x 5.1mm.

Chlorid analyses

The rate of chloride penetration into the bio ash concrete was determined to be 8.2mm/år$^{1/2}$, which is considered a rather high value. The diffusion coefficient of the bioash concrete was approximately the same, 3.8 x10^{-12} m^2/s, after 28 and after 110 days, while the diffusion coefficient of comparable conventional concretes was significantly lower after 110 days compared to after 28 days. However, the effect of bioash on the test method is not known, so the results need to be evaluated with caution.

Compressive strength of drilled cores

Three cores were taken of the bioash concrete and tested for strength in compression. The average strength was found to be 68 MPa when corrected to cylinder strength.

Water basin

Due to its underground location it was not possible to do a visual inspection of the bioash concrete covering the PPE pipes. It was not possible either to obtain enough material samples to do compressive strength and chloride diffusion testing.

Petrographic ”structure” analysis

The analysis showed that in general the concrete is in good condition although some defects from the casting process were observed.

Generally, no cracks are observed in the concrete. The few cracks that can be observed are fine cracks primarily found at the concrete surface. The cement paste revealed good hydration of a fine to medium grained Portland cement having low ferrite content. The paste contains considerable amount of fly ash. The fly ash content is estimated to by more the 30% of the total powder content. Approximately 10% of the powder consists of well-distributed reddish bioash. The water to cement ratio of the interior concrete is estimated to be 0.55-0.60 and the paste is somewhat inhomogeneous. At the surface the water to cement ratio appears to be higher than in the interior (Figure 6). Locally, increased capillary porosity is observed at the surface as well as at the interface between aggregate and paste (Figure 7). The concrete is air entrained, but does also contain entrapped air as 3-7mm irregular and rounded voids.

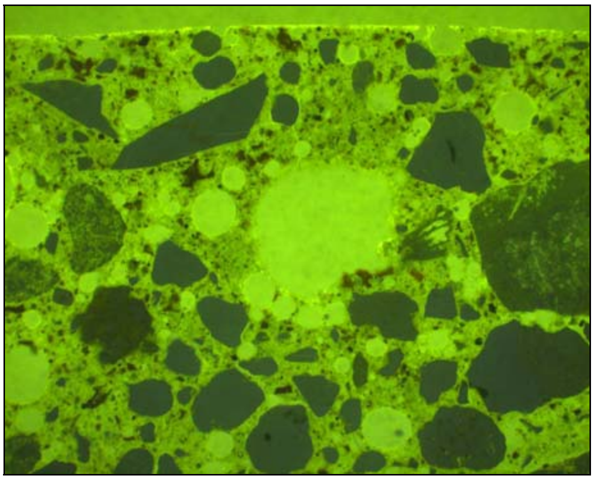

Figure 6. Image showing the surface of the bioash concrete. A fine crack is observed perpendicular to the surface towards the large air void. The very light green colour suggests that the concrete has a high w/c ratio. Fluorescent light mode, field of view 3.8mm x 5.1mm.

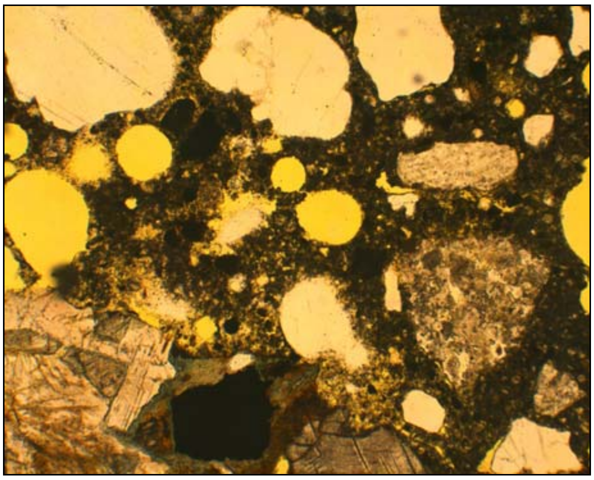

Figure 7. Image showing the interior of the concrete. An area of high porosity is seen along the paste aggregate interface. The concrete contains some rounded air voids. Polarized light mode, field of view 3.4mm x 4.3mm.

The individual bioash particles have well-defined edges even when the particles geometry is complex and the specific surface apparently high (Figure 8). This indicates that no hydration/reaction has taken place between the bioash and the other constituents of the cement paste.

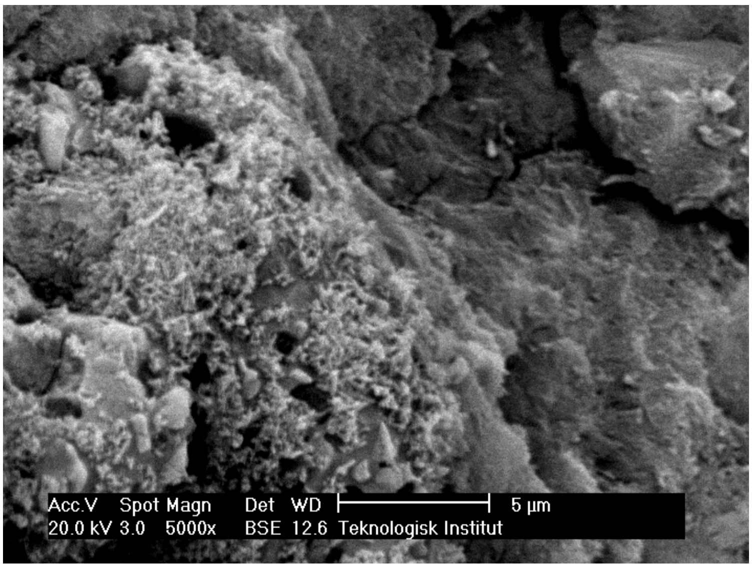

Figure 8. The rough and irregular surface of a bioash particle.

3. Evaluation

Demo bridge
The bioash concrete of the demonstration bridge shows all the signs of being a healthy durable concrete. The microstructure does not show any significant defect originating from the plastic or hardened state of the concrete, i.e. it is properly placed and cured concrete of adequate composition.

No evidence was obtained that the bioash particles take part in hydration reactions or other chemical reactions in the cement paste.

The chloride penetration into the bioash concrete is higher the expected. A possible reason is the fact that the bioash concrete was cast on November 1st, 2002 at fairly low temperatures right before winter time, whereas the bridge deck etc. was cast in late March 2002. The bridge was put into service already on December 17th, 2002 meaning that the bioash concrete compared to the bridge deck had significantly less maturity when first exposed to chloride ions, i.e. the bioash concrete was not as dense as the bridge deck when first exposed to chloride.

Water basin
The bioash concrete of the water basin is generally in good condition and based on the microscopy analysis the compressive strength is estimated at around 20 MPa. The concrete has a high water to cement ratio, and areas of increased porosity due to short plastic cracks originating from the first few hours from placements are observed.

Observations in the scanning electron microscope do not suggest that bioash particles have reacted at all within the cement paste, i.e. any strength contribution from the bioash is most likely due a filler effect.

Comparison between bioash concrete and conventional concrete
This report is based on two investigations of concrete made with bioash – a high strength concrete and a low strength concrete. Currently, both concretes perform well and exhibit properties that do not deviate significantly from comparable conventional concrete without bioash.

As all Danish bioash concrete the investigated concretes are still young, less than 5 years of age, and consequently it has not been possible to evaluate their long-term durability performance. However, there are no signs that the long-term durability will develop any different than expected for comparable conventional concrete.