Concrete Based Parts for High Precision Applications

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Abstract

In previous studies we have shown that Self Compacting Concrete (SCC) is a promising alternative material for machine parts in high precision applications conventionally designed of natural stone. Parts with comparable functional surface finish and mechanical properties to those made of natural stone can be done in shorter time at lower cost starting from small lot sizes. The developed "ready-to-use" primary shaping process offers vast freedom of design compared to machined natural stone [1]. In current studies, both moulding and post moulding processes have been optimised. This article shows that a major improvement in long-term form stability, time to stabilisation and surface roughness of moulded parts has been achieved.

1 Introduction

In previous studies the feasibility and the technology for achieving high precision smooth and levelled functional surfaces at spacious parts with a flatness in the micrometre range with standard SCC in a mould process have been demonstrated [1]. In current research the SCC mixtures were modified to achieve optimal material properties comparable to parts made of natural stone. The modification can be done in three ways: Using a high powder content (powder type), a viscosity modifying agent (viscosity modifying agent type) or both (combination type) [2]. The latest developed concretes are powder type SCCs. Two different cements (CEM I 42,5 R and CEM II/A-LL 42,5 R), silica fume and fly ash as powder components were used. In order to achieve high values in strength and Young´s modulus, basalt gravel and sand were used for the coarse and fine aggregates respectively. The grading curve was calculated according to Hüsken and Browers [3] to achieve the highest possible packing density. A PCE superplasticiser ensures the viscosity of the SCC mixtures. As a mould a reinforced frame design using plastic surfaces was fixed on top of a high precision natural stone plate forming the reference face for the functional surface of the part to mould. Polyethylene foil was applied as a barrier layer to protect the natural stone and guarantee a surface roughness of less than 2 µm.

2 Experimental results

Concrete properties were tested in fresh and cured state and optimised for the intended applications which demand higher strength and stiffness values as seen in table 1. For the experiments concrete beams of 1400 x 80 x 160 mm³ were produced and their roughness, flatness deviations and time dependent deformations were measured, using a roughness meter and an autocollimator respectively.

Table1: Cured SCC properties compared with granite and standard concrete [1]

	unit	granite	concrete	SCC I	SCC II
compr. strength	[N/mm²]	250 - 360	5 - 55	110.1	109.2
flexure strength	[N/mm²]	10 - 35	2 - 8	8.1	7.7
Young´s modulus	[kN/mm²]	60 - 95	21.8 - 34.3	45.4	44.4
density	[g/cm³]	2.90	2.0 - 2.6	2.48	2.47

2.1 Short range quality of moulded surfaces

Figure 1 displays the unfiltered roughness profiles of the samples. Beam 1 shows a surface roughness R_z of 1.47 µm and a roughness average R_a of 0.16 µm without post processing. These values are better than those of common granite surfaces used

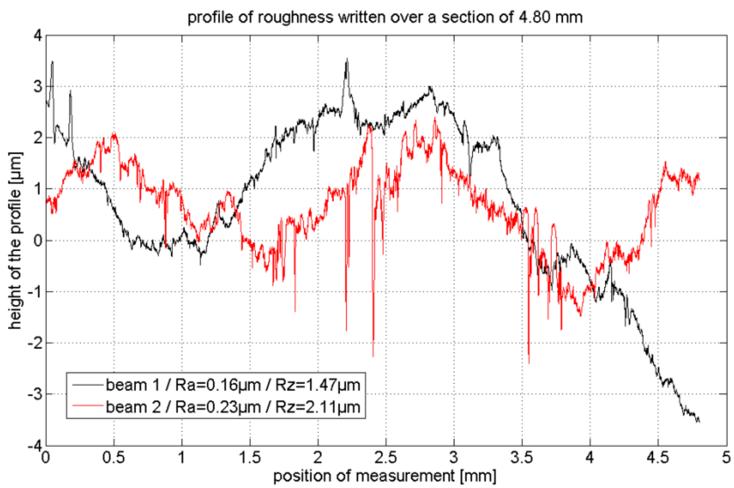

Figure 1: roughness of special SCC surfaces

for air bearings (R_z = 5.2 µm, R_a = 0.56 µm) [1] In comparison to earlier studies with standard SCC the roughness has been decreased by 30%. The plot of beam 1, moulded on a 100 µm thick foil shows a lower frequency but higher amplitude of the waviness than beam 2 moulded on a 25 µm foil (figure 2). The visible waviness is caused by inhomogeneities of the barrier foil's stiffness and thickness. The search for high quality foil that meets all requirements is part of future studies.

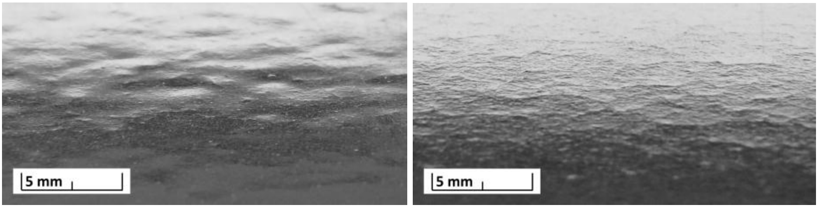

Figure 2: waviness of special concrete surfaces (left: beam 1, right: beam 2)

2.2 Long range quality of moulded surfaces

Quelling and shrinking has a significant influence on the flatness of concrete parts. That is why concrete parts casted on a best flat standard plane bulge out in form of a bending line. Figure 3 shows the maximum deformation of 1400 mm long sample beams during a time period of over 100 days after casting. A granite reference beam

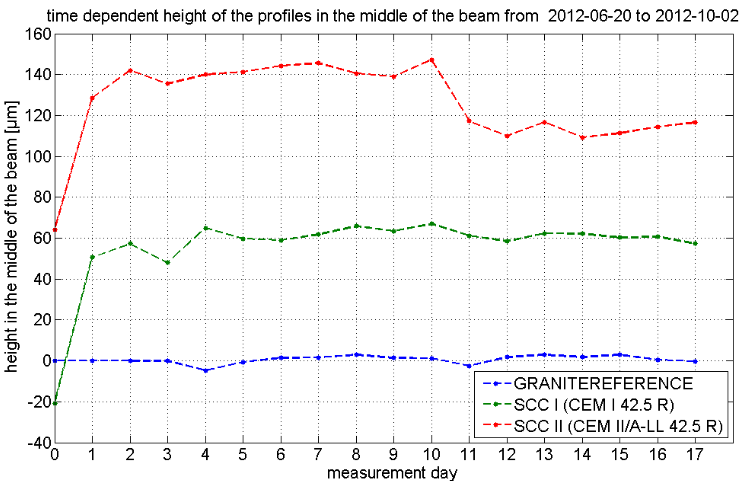

Figure 3: Long-term behaviour of the flatness of beams made with special SCC

is plotted for comparison. The maximum deformation of the test beam made of SCC I is less than 60 µm which is an improvement of over 55% compared to previous results [1].

After a period of about 4 weeks under laboratory conditions the concrete beams show a good long-term stability comparable to the granite reference beam. To investigate the influence of humidity, the SCC II and the granite reference beam were treated with 100% relative humidity for two days between measurement day 10 and 11. The deviation of the SCC II beam decreased by 25 µm while the granite beam did not show any reaction to this treatment. Future studies will address this effect.

3 Conclusions

Concrete parts having functional surfaces with a roughness appropriate for aerostatic guideways can be created by a “ready-to-use” mould process. Latest concrete compositions show excellent long-term stability and mechanical properties comparable to natural stone. Test beams with a length of 1400 mm and an absolute maximum straightness deviation of 60 µm were casted. After the concrete has cured, the long-term stability resembles the behaviour of granite. The research is now focussing on the sensitivity to humidity and other environmental influences to create parts that are feasible at normal environmental surroundings beyond the laboratory.

Acknowledgments:

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