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SUMMARY

F 7038

Application Rules for Ground Granulated Blast Furnace Slag as Concrete Additive According to the Harmonised European Standard

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In this research project the properties of concrete made with ground granulated blast furnace slag (ggbfs) according to DIN EN 15167-1 where investigated. This product standard defines the requirements on ggbfs; specifications for the use of ggbfs as an additive for concrete (type II) are not given. For this purpose national application rules have to be formulated. It was the aim of this research project to create a database for the development of these application rules. Especially the cement equivalent effectiveness (k-value) of ggbfs according to DIN EN 15167-1 should be proved on the basis of experiments. Apart from the deduction of a k-value it was checked whether a use according to the exchange concept is possible.

Five different granulated blast furnace slags have been chosen. They were delivered to ibac in granular form and ground for this project in particular. The grinding fineness was supposed to be close to the minimum requirements of DIN EN 15167-1 in order to enclose the low grade ggbfs as well. The choice of the ggbfs was also geared to the minimum requirements of the standard. The chemical composition of the ggbfs fulfilled the requirements of DIN EN 15167-1, but the demanded activity index and the grinding fineness was not reached by one of the five ggbfs.

The ggbfs were tested in combination with a CEM I 32,5 R, a CEM II/B-S 32,5 R and a CEM III/A 32,5 N respectively. At first the relative compressive strength of mortar (related to the strength of the reference mortars) was tested for all combinations of cements and ggbfs. The chosen ratios of ggbfs / cement (h/c-ratio) ranged from 0.25 to 1.5. As it was expected the relative strength decreased with increasing ggbfs-content of the cement and with increasing h/c-ratio.

On concrete with h/c-ratios ranging from 0.33 to 1.0 the k-values of four ggbfs were determined at the age of 7, 28 and 56 days. However it was not always possible to determine a reliable k-value because the compressive strength of the concretes with ggbfs was sometimes remarkably lower than the strength of the reference concretes. The reason for this was that the cement was replaced 1:1 by ggbfs, this means that the expected k-value was 1.0. However this k-value was far from the actual one. The data at hand implies that the minimal k-value of ggbfs according to DIN EN 15167-1 lies between 0.4 and 0.6 at an age of 28 days. Only the most reactive ggbfs can be applied according to the exchange concept. Due to there higher fineness usual ggbfs on the market will probably reach higher k-values depending on the h/c-value. A k-value of 1.0 seems to be realistic for h/c = 0.33 and a grinding fineness of ≥ 4000 cm²/g (Blaine-value) for the ggbfs. To take advantage of these k-values it would be necessary to define several quality levels.

Apart from the testing of compressive strength the durabilty was investigated concerning the carbonation behaviour, the electrolyte resistance and the frost- and freeze-thaw salt resistance. Carbonation was tested on concrete samples (70 · 70 · 250 mm³). For comparison six mixtures with h/c = 0.33 were examined according to the test procedure of the DIBt on bars made of fine grained concrete (40 · 40 · 160 mm^3). The investigations with concrete samples showed that the velocity of carbonation increases with increasing ggbfs content and decreasing Portland cement content. Thereby it is unimportant whether the ggbfs originates from the cement or is added as additive. By using the test procedure with fine grained concrete the concretes with high ggbfs content are evaluated too negatively, because the dehydration of the small specimens is much higher than the dehydration of concrete. This is even more the case when the ggbfs concrete is compared to concretes with a high Portland cement clinker content, because these concretes show a slower carbonation of fine grained concrete compared to normal concrete.

For the testing of the frost- and the freeze-thaw salt resistance two ggbfs were used with an h/c-ratio of 0.33. An other ggbfs was tested with h/c = 1.0 additionally. CEM I 32,5 R and CEM II/B-S 32,5 R were used for these tests. In the composition of the concretes the identified k-values were accounted. The suitability for exposure class XF3 was verified for all 10 concretes using the test procedure described in DIN CEN/TS 12390-9, chapter 6. The weathering was ≤ 2,5 M.-% after 100 freeze-thaw-cycles. In the test of the freeze-thaw salt resistance (CDF-test) the permissible weathering of 1500 g/m² was exceeded by the concrete with h/z = 1,0 and CEM II/B-S 32,5 R.