Influence of curing temperature on development of compressive strength and resistance to chloride ingress of concrete with different binder systems

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EXTENDED ABSTRACT

This investigation is part of the work undertaken in the Expert Centre for Infrastructure Constructions – a joint 2½ year project between the Danish Technological Institute and the Technical University of Denmark co-financed by the Danish Ministry of Science, Technology and Innovation. The primary scope was to test the application of the maturity concept to modern concretes used in aggressive exposure environments, as well as to establish a relation between mechanical properties and durability performance as a function of curing temperature.

Seven concretes with different binder compositions were cured at five different temperatures. The development of compressive strength and resistance to chloride ingress was tested at similar

ages calculated using the existing Danish maturity concept. An overview of the testing program is presented in Figure 1 below.

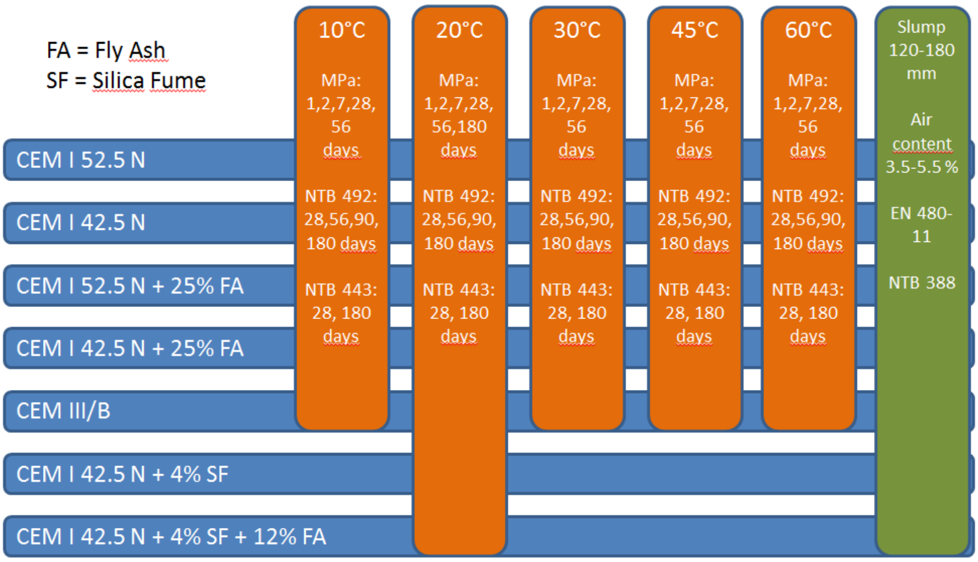

Figure 1 - Schematic overview of the examined concrete compositions and testing procedure

The actual curing times for testing at the same maturity were estimated by applying temperature rate constants of 0.50, 1.57, 2.95 and 5.22 for 10, 30, 45 and 60 °C respectively in accordance with the existing maturity concept (Freiesleben Hansen, P. and Pedersen J., "Maturity computer for controlled curing and hardening of concrete, Nordisk Betong 21, 19-34, 1977).

The concretes tested were produced using quartz dominated sea dredged 0/2 mm as fine aggregate and granite in the fractions 4/8 mm, 8/16 mm and 16/22 mm as coarse aggregate. For all concretes the water to cement ratio was controlled to within 0.002 of the target 0.400. The target air content of the concrete was 4.5 %. The total binder content was 360 kg/m^3 for the pure cement concretes and 400 kg/m^3 for the concretes with 25 % fly ash.

The concrete was produced using the mixing plant at the DTI Concrete Centre which has a capacity of 250 liter concrete. For each concrete type, 500 liter (2 batches of 250 liter) concrete was produced for the casting of 78 Ø150 cylinders (for strength development, 3 per test) and 32 Ø100 cylinders (for NT Build 492+443 and EN 480-11).

Immediately after mixing, the fresh concrete properties were determined. Subsequently, the cylinders were cast and the forms immersed in temperature controlled water tanks. The cylinders were demoulded the following day and placed in the water tanks again until testing. The 30, 45 and 60 °C specimens for testing at 1 day maturity and the 45 and 60 °C specimens for testing at 2 days maturity were demoulded just before testing.

Currently not all results from the test program are available as the required maturity has not been reached for all specimens.

However, regarding the strength development a decrease in strength with increasing curing temperature was observed for fixed maturity for all binder systems. This effect was especially pronounced for the pure CEM I concretes, where a 25 % decrease in strength at 28 days maturity was observed comparing data for curing at 30 and 60 °C respectively. This result would not be predicted by applying the maturity function.

Figure 2 shows the strength development as a function of temperature and curing time for binder systems CEM I 42,5N + FA (left-hand) and CEM III/B (right-hand). It is seen that the strength development of the binder system with fly ash is enhanced with increasing temperature except for curing at 60C which results in a significantly reduced ultimate strength. On the other hand the ultimate strength of the binder system with slag seems in general negatively affected by increasing curing temperatures.

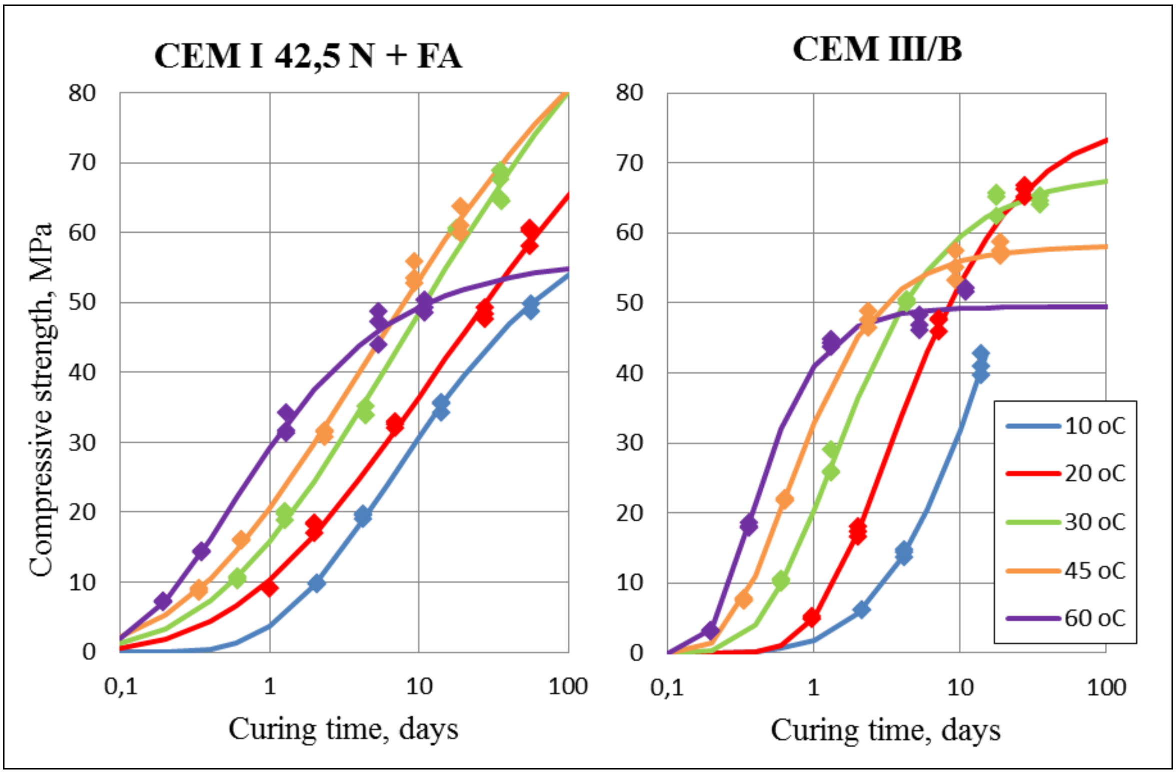

Figure 2 - Strength development as a function of temperature and curing time for binder system CEM I 42,5N + FA (left-hand) and CEM III/B (right-hand).

Regarding the chloride migration coefficient (CMC) determined according to NT Build 492, a highly interesting and surprising behaviour was observed. For the pure CEM I concretes, the CMC at similar maturity increases with increasing curing temperature, while the opposite is observed for the fly ash concretes (Figure 3). For the CEM I 42.5 + FA concrete, the CMC at 28 days maturity is 10 times lower for a curing temperature of 60 °C than for a curing temperature of 10 °C. The concrete with slagcement (CEM III/B) has the lowest CMC at all studied curing times and temperatures, and is very little affected by the curing temperature.

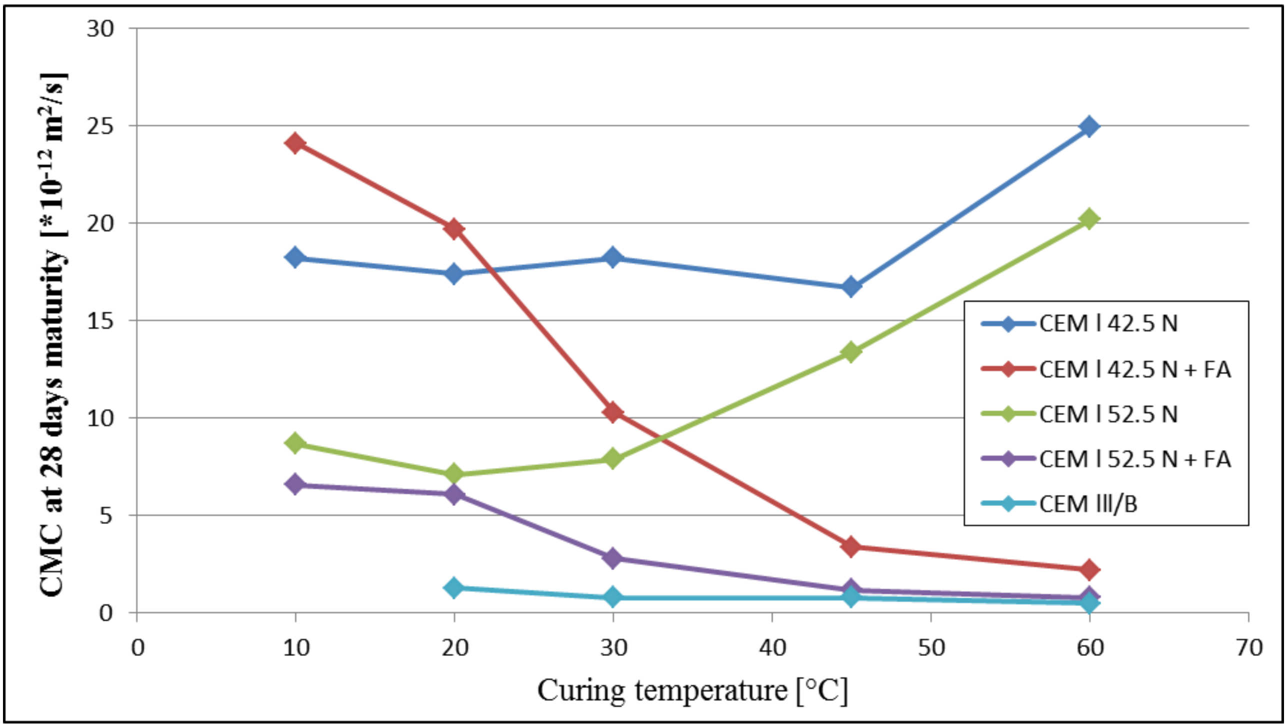

Figure 3 – Development of chloride migration coefficients as a function of binder system and curing temperature