ON THE EFFECT OF SUPERABSORBENT POLYMERS ON COMPRESSIVE CREEP OF CONCRETE

ZUM EINFLUSS SUPERABSORBIERENDER POLYMERE AUF DAS DRUCK-KRIECHEN VON BETON

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SUMMARY

Experiments have been carried out on concrete with and without Superabsorbent Polymers (SAP). Pairs of concretes with SAP and the same total water content as concrete without SAP are compared with respect to strength, stiffness and specific creep. It is shown that SAP reduces strength and stiffness and, as a main result, also specific creep under compressive loading.

ZUSAMMENFASSUNG

Experimente an Betonen mit und ohne superabsorbierenden Polymeren (SAP) wurden durchgeführt. Betone mit demselben Gesamtwassergehalt, einmal als Anmachwasser und andrerseits teilweise in SAP gespeichert, wurden paarweise hergestellt und werden verglichen. Es zeigte sich, dass SAP sowohl Festigkeit wie Steifigkeit reduziert, aber auch, und das ist ein wesentliches Ergebnis, das Grund- und das Trocknungskriechen.

1. INTRODUCTION

Superabsorbent polymers (SAP) are a new class of additives to concrete which have an effect on fresh and hardened concrete properties. An overview can be found in [1]. Main emphasis in past and recent research is laid on analyzing the chemical composition of SAP and, as the concrete in the field is concerned, on mitigating shrinkage and supporting internal curing. There are other aspects which deserve more attention one of which is the creep behavior. The present experimental investigation on a limited number of specimens deals with creep under compressive loading. Structural engineers of course are aware of the effect of creep on the deflection of bending members, on the partial release of prestressing and, on the other hand, on the relaxation of stresses due to imposed deformation.

2. CONCRETES

2.1 CONCRETE COMPOSITION

SAP can store water und release it during hydration of the cement. To investigate the influence on creep the composition of the mixes was chosen such that a pair had the same total water content. One concrete (designated as “Reference”) had the water as mixing water, the other (called “SAP”) had it partly as mixing water and partly stored in the SAP. The selected polymer from BASF was a polyacrylamide with particle size ranging up to 100 mm. Fig. 1 shows scanning electron micrograph from the selected SAP. As cement an ordinary Portland cement CEM 42.5 R was used (63.1% CaO, 19.9% SiO_2, 5.7% Al_2O_3, 2.9% Fe_2O_3, 0.7% K_2O, 0.13% Na_2O, 2.0% MgO, 3.6%, SO_3, 0.3% TiO_2, 0.5% P_2O_5, 0.06% MnO, 0.1% SrO). The cement content was the same for all mixes. In order to keep the workability of the mixes almost the same, plasticizers had to be added. The aggregates followed rather closely the Fuller curve up to 8 mm. Table 1 shows the composition.

In order to see the influence of drying on creep two storage conditions were chosen after two days in the mold: either 14 days in fog room and then open in laboratory climate 20°C and 65% RH leading to drying creep or sealed in aluminium foil leading to basic creep.

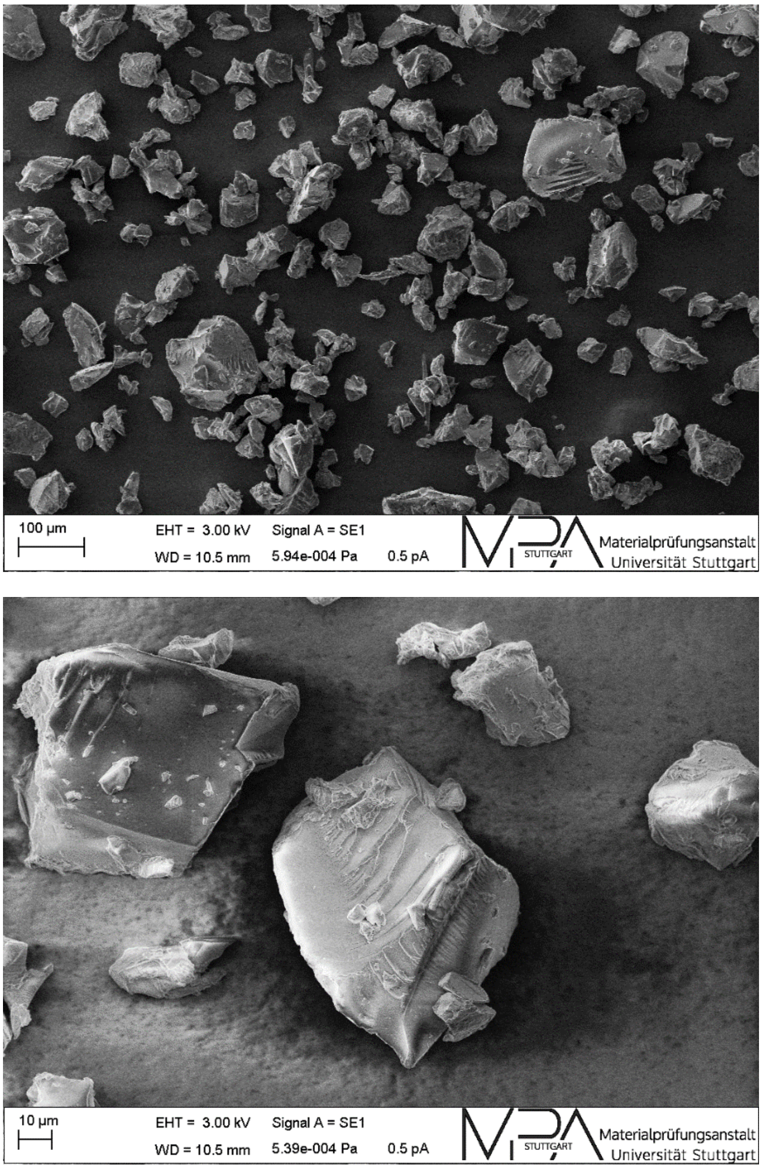

Fig. 1: Scanning electron micrographs of used SAP

Table 1: Composition of the mixes in kg/m^3

	Reference (Ref)			SAP modified (SAP)	
Water-to-cement ratio	0.50	0.42	0.36	0.42 + 0.08	0.36 + 0.06
Cement CEM I 42.5 R	450	450	450	450	450
Water	225	189	162	225	189
Super plasticizer	-	0.85	2.72	5.36	7.74
SAP	-	-	-	1.58	1.17
Aggregate 0/8 mm	1629	1725	1796	1629	1725

2.2 HARDENED CONCRETE PROPERTIES

SAP introduces pores in the mix which have an effect on strength and elastic modulus, i.e. strength and stiffness of SAP modified concrete are reduced as can be seen in Table 2.

Table 2: Strength and elastic modulus of concrete at an age of 28 days

Concrete	Ref 0.50		Ref 0.42		Ref 0.36		SAP 0.42 + 0.08		SAP 0.36 + 0.06	
Sealed	Yes	No	Yes	No	Yes	No	Yes	No	Yes	no
Density [kg/m³]	2312	2312	2338	2363	2375	2379	2284	2314	2345	2393
Cylinder strength [MPa]	54.1	54.9	65.3	60.1	68.1	72.7	40.4	43.4	52.2	57.8
Static elastic modulus [GPa]	33.4	30.5	38.2	36.4	38.9	38.3	30.2	31.8	35.4	37.9

SAP can promote internal curing which was manifest in a strength increase of about 30% after storage up to 360 days compared to only 10% of reference concrete.

3. COMPRESSIVE CREEP TESTS

3.1 LOADING

Creep tests have been performed in a device as shown in Fig. 2. The load was applied by a hand pump and kept constant by Belleville springs, strains were measured by inserted Linear Voltage Differential Transformers (Fig. 3). The specimens were cylinders with 150 mm diameter and 300 mm height. Testing took place in climate room 20°C and 65% RH. The constant load corresponded to 25% of 28 days cylinder strength.

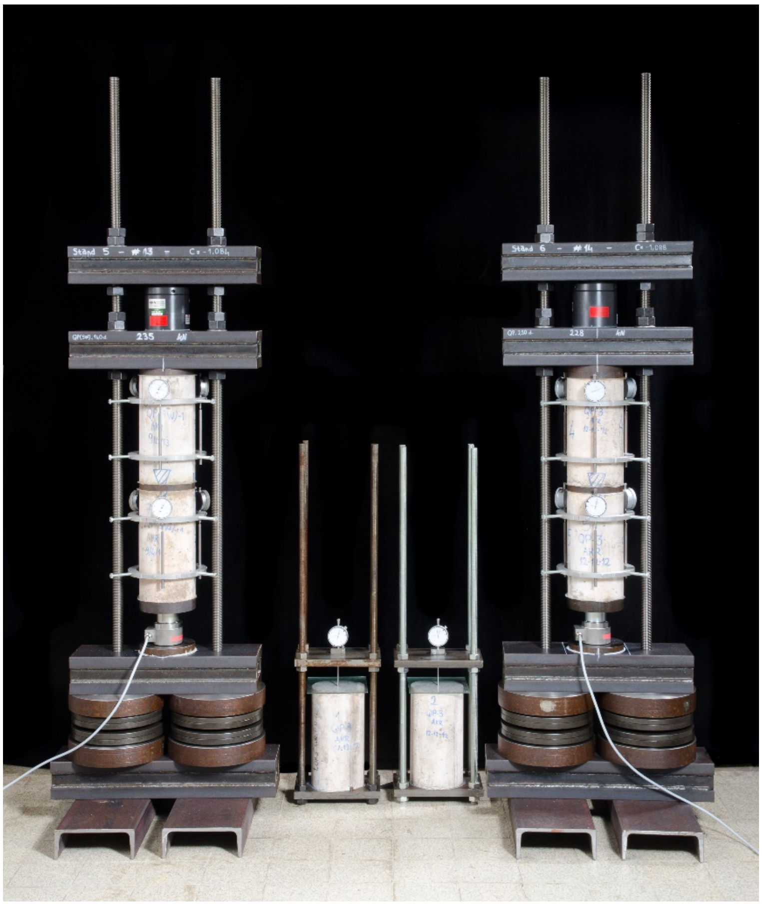

Fig. 2: Example of the creep and shrinkage rigs

Fig. 3: Cylinder for creep test (left) and split cylinder showing interior Linear Voltage Differential Transformers (LVDT) for creep test (right) (source: [2]).

3.2 TEST RESULTS

Parallel to creep tests, shrinkage was measured on companion specimens stored in analogous environment (Fig. 2). The total deformation of a drying and loaded specimen at constant temperature is given by

$$\varepsilon_{tot}(t,t_d,t_o) = \varepsilon_{as}(t) + \varepsilon_{ds}(t,t_d) + \varepsilon_{el}(t_o) + \varepsilon_{bc}(t,t_o) + \varepsilon_{dc}(t,t_d) \quad (1)$$

with t = age of concrete, t_d = age at begin of drying, t_o = age at load application. Strain is designated as ε_{as} = autogenous shrinkage, ε_{ds} = drying shrinkage, ε_{el} = elastic or initial strain at loading, ε_{bc} = basic creep, ε_{dc} = drying creep. In this investigation, only creep is of interest, therefore the elastic and shrinkage strains were subtracted from total strain, all zeroed at 28 days. Since loading was a fraction of strength and strength was not the same for all mixes, creep strain is divided by the applied stress which yields the specific creep. Table 3 shows the result.

Table 3: Specific creep in (mm/m)/MPa at end of lading at 270 days

Concrete	Ref 0.50	Ref 0.42	Ref 0.36	SAP 0.42 + 0.08	SAP 0.36 + 0.06
Specific basic creep	0.080	0.044	0.036	0.050	0.038
Specific drying creep	0.100	0.084	0.058	0.074	0.064
Difference	0.020	0.040	0.022	0.024	0.026

There are two main results: First, drying creep is always larger than basic creep, second, SAP obviously reduces creep. These statements will be analyzed more in detail.

The wording “drying” creep should be understood as the creep which is measured in simultaneous drying conditions and which comprises basic creep and an additional amount which is due to water movement during drying. The difference between the two environments is in the range of 0.020 and 0.040. Looking to the mixes with the same total water, for instance, Ref 0.50 and SAP 0.42 + 0.08 a reduction of 0.030 for basic creep and 0.026 for drying creep can be seen. In case of Ref 0.42 and SAP 0.36 + 0.06 the numbers are 0.006 and 0.020. The conclusion is that SAP reduces creep in both environments. Many more tests have to be executed in order to substantiate the statements.

4. DISCUSSION

Usually, two assumptions are deduced from experiments: First, higher water-to-cement ratio, or in other words, higher water content leads to more creep and second, higher strength leads to less creep. The first statement is verified by the current compressive experiments. The second statement was not supported by all experiments since the SAP modified concretes had lower strength than the Ref mixes and had nevertheless lower creep. That means that obviously SAP had a significant effect on creep. The environment was not decisive for the effect on the simultaneous influence of SAP on creep. The number of tests (two per parameter combination) is too small in order to draw sound conclusions. Much more experiments have to be carried out in order to validate the apparent trends.

5. CONCLUSION

Experiments have been carried out in to investigate the influence of superabsorbent polymers (SAP) on creep of concrete. To this end, pairs of mixes with the same total water content were made either with the water as mixing water or partly stored in SAP. Two environments were chosen, one drying in the laboratory climate 20°C and 65% RH or second, sealed by aluminum foil.

The main findings are:

1) SAP seems to reduce basic as well as drying creep significantly.
2) Although the strength of SAP mixes with the same total water content was smaller than without SAP basic and drying creep was reduced.
3) Drying creep was always larger than basic creep.
4) It must be noted that only a limited number of experiments yielded these findings. For a more substantial conclusion more tests have to be carried out which is highly recommended.

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