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Development of Elasticity Modulus in Time for Concrete Containing Mineral Admixtures

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***Abstract*—**This paper introduces selected composition of conventional concretes and their resulting mechanical properties at different ages of concrete. With respect to utilization of mineral admixtures, fly ash and ground limestone agents were included in addition to pure Portland binder. The proposal of concrete composition remained constant in basic concrete components such as cement and representation of individual contents of aggregate fractions; weight dosing of admixtures and water dose were only modified. Water dose was chosen in order to achieve identical consistence by settlement for all proposals of concrete composition. Mechanical properties monitored include compression strength, static and dynamic modulus of concrete elasticity, at ages of 7, 28, 90, and 180 days.

***Keywords*—**Cement, mineral admixtures, microstructure of concrete, mechanical properties.

I. Introduction

THE objective of the draft composition of current trends in proposing concrete compositions is to optimize individual input components. Environmental requirements are the essential part of current trends and fundamentally modify draft compositions of concretes. At the present time, the production blended cements increases, as they are included in the widest assortment of concretes. At the same time, both, active and partially also passive admixtures are increasingly being used as independent input components in concrete, in consideration of positively affecting binding properties.

A. Mechanical Properties of Concrete

Mechanical properties of the material indicate the relation between mechanical stress and resistance, by which the material resists to such stress [1], [2]. The most important mechanical properties of concrete are its strength and deformation. In case of mechanical stress only, mechanical properties are identified as deformational or strength properties [2]. In principle, physical-mechanical properties of concrete may be modified as early as in the stage of construction-technical design of the structure by choosing appropriate raw materials [3]. In concretes for conventional structures, the compression strength can be considered the crucial property characterizing the quality of concrete, since the factors that influence the compression strength of concrete also influence its other properties [4]. Properties of set concrete result from many effects, starting with the type and characteristics of input components used for the production, composition and production method of fresh concrete, transport to the storage point, storage method, compacting, treatment during maturing, conditions of its use, and possibly other factors [4], [5]. Mechanical properties of concrete are primarily influenced by microstructure of set cement and filling agent characteristics. Concrete is a complex composite system, which depends in particular on cooperation of all components except for environmental effects [5]. From the general perception of concrete as a homogeneous and isotropic material, the set cement paste and the layer between aggregates and the set cement paste [6], the so-called transit zone, may be considered the weakest component of concrete structure influencing mechanical properties of concrete. Modern approaches of current concrete technology enable to modify the transit zone and thus indirectly improve the mechanical properties of concrete as well. We may achieve such modification using fine active mineral admixtures modifying the microstructure of concrete and thus also the interlayer between the cement matrix and the binding agent.

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II. Experimental Part

The concept of concrete design was based on the proposal of the reference formula and subsequently on the modification of this formula incorporating mineral admixtures in the concrete system. Fly ash and ground limestone were used as admixtures. Brown-coal fly ash, with the specific surface of 520m^2/kg, and fine-ground limestone CL09 were used. Four formulas have been prepared, of which the reference formula only included Portland cement CEM I 42.5 R as a binding agent. The second formula combines 390kg/m^3 of Portland cement and 56kg/m^3 of ground limestone. The next concrete formula reduces the amount of Portland cement to 370kg/m^3 and the limestone to 50kg/m^3. The last formula combines 380kg/m^3 of Portland cement and 90kg/m^3 of fly ash. Aggregates were used in fractions 0-4 and 8-16mm. Aggregate dose amounted 865kg/m^3 or 870kg/m^3 for fraction 0-4mm, and 940kg/m^3 or 945kg/m^3 for fraction 8-16mm. For concrete production, a plasticizer of water solution of naphthalene based sulphonated polycondensate was used in a dose of 0.85 to 1% of the cement volume, and the water-cement ratio was set to 0.43, 0.43, 0.46, and 0.44.

A. Properties of Fresh Concrete and Mechanical Properties of Concrete

Individual concrete formulas are indicated TC_Ref, TC_Lim1, TC_Lim2, TC_F, where TC_Ref indication specifies reference concrete with Portland cement only, TC_Lim concretes with limestone, and TC_F formula concrete with fly ash.

Consistency of fresh concrete using the cone settlement test and specific density of fresh concrete were observed. The results found are shown in the following table. We tried to produce fresh concrete of identical consistence to be able to compare mechanical values for concretes featuring the same workability.

TABLE I
PROPERTIES OF FRESH CONCRETE

Concrete	Density of fresh concrete [kg/m^3]	Slump [mm]	Class of slump [-]
TC_Ref	2430	100	S3
TC_Lim1	2420	105	S3
TC_Lim2	2390	110	S3
TC_F	2370	120	S3

The following table shows the summary of all results achieved. Compression strength, static modulus of elasticity in compression, and dynamic modulus of elasticity determined by ultrasonic pulse method were monitored in individual concretes. Development of these specific concrete properties was monitored at ages of 7, 28, 90, and 180 days.

TABLE II
MECHANICAL PROPERTIES OF CONCRETE

Properties	Days	TC_Ref	TC_Lim1	TC_Lim2	TC_F
Compressive strength [MPa]	7	34.2	39.6	32.5	36.3
	28	44.4	42.1	38.2	46.0
	90	46.1	47.2	41.1	54.1
	180	48.2	50.1	45.1	57.8
Static modulus of elasticity [MPa]	7	31500	29500	27500	29000
	28	33000	32000	31000	31000
	90	33500	34000	32500	34000
	180	34500	35000	33500	34500
Dynamic modulus of elasticity [MPa]	7	41900	40600	39700	39000
	28	42200	42200	40100	40500
	90	42900	42600	40700	40700
	180	42900	42700	40800	41000

III. EVALUATION

By obtaining all measured data of resulting values of mechanical properties, we were able to prepare graphic interpretation of individual characteristics. Time development of the static modulus of concrete elasticity was monitored in the first stage, whereas the second stage focused on the development of the dynamic modulus of elasticity.

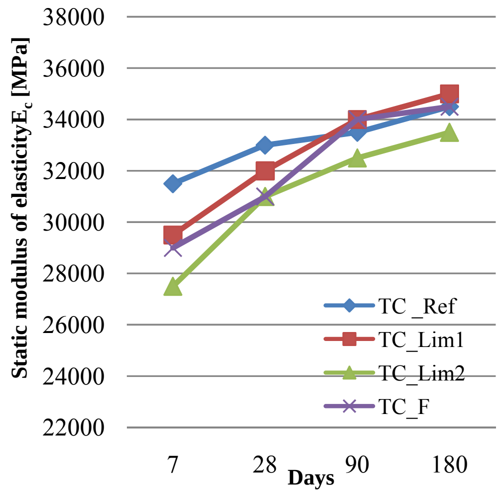

Fig. 1 Development in time of static modulus of elasticity in compression

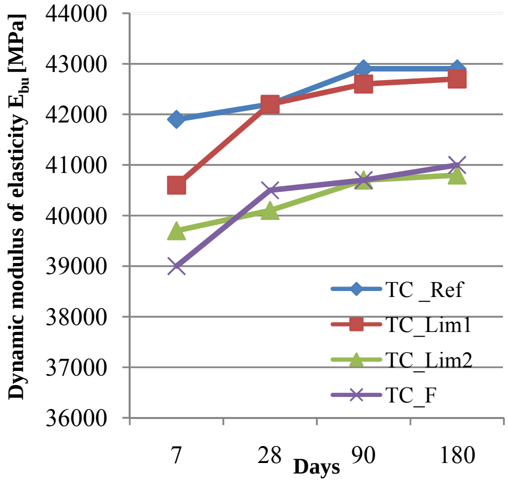

Fig. 2 Development in time of dynamic modulus of elasticity

It is apparent from Fig. 1 that highest initial values and values at the age of 28 days are achieved by reference formula using TC_Ref cement only. The most significant progress in the static modulus of elasticity is achieved in the period between 28 and 90 of age by formula with limestone TC_Lim1 and formula with fly ash TC_F, where more than 3000 MPa increase was observed, as compared with an increase of 500 MPa only for the reference formula. The highest dynamic modulus of concrete elasticity was observed in the reference formula, reaching the highest values for the whole period of monitored age of concrete. On the other hand, the formula with fly ash TC_F did not show the same increase of values as in case of the static modulus of elasticity in time, and it did not reach values of the reference formula at any age of concrete. From both the static and dynamic development point of view, TC_Lim1 is the most significant formula, achieving the best values in both cases as compared with the reference formula TC_Ref.

At the age of 28 days, concrete achieves specific, required, and declared properties. For this reason, the dependency between compression strength and static modulus of elasticity was monitored at the age of 28 days only.

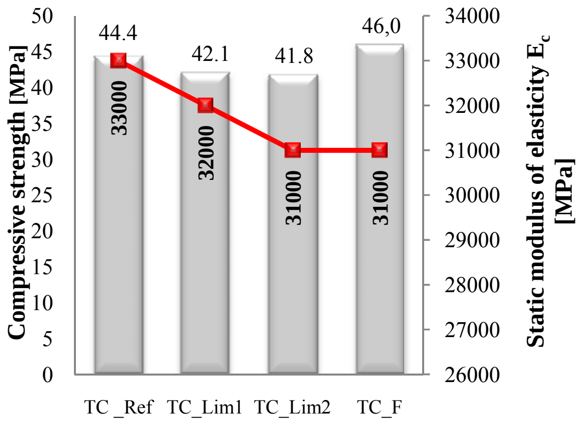

Fig. 3 The relationship between the compressive strength and static modulus of elasticity of concrete at 28 days

It is apparent from Fig. 3 that the highest values of the elasticity modules at the age of 28 days are achieved by reference formula using only Portland cement as a binding agent. On the contrary, the formula with fly ash TC_F achieves the highest compression strength, although the difference is not significant and we are still at the border of the same structural class. The results of mechanical properties of the formula with ground limestone TC_Lim1 are the closest to the reference formula using cement only as a binding agent.

IV. Conclusion

The paper deals with an issue of partial replacement of Portland cement with a mineral admixture, whereas the impact of such intervention into concrete draft composition on mechanical properties of concrete was reviewed. In particular modules of elasticity, the static modulus of compressive elasticity, and the dynamic modulus of elasticity of concrete were reviewed. In both cases of measured modules of elasticity, the highest values of both, at the age of 28 days and in time, were achieved by the reference formula with cement only. On the contrary, in concretes with mineral admixture, the specific feature of concretes with mineral admixture became evident, i.e. concretes with admixtures at this age often do not achieve identical values as concretes with cement only. This feature is attributed to slower onset of hydration reactions. However, the trend of increased or even exceeded values of the reference formula became evident mainly in case of static modules of elasticity in concrete with fly ash. The paper shows that by appropriate composition of concrete raw materials, and also in case mineral admixtures are used, it is possible to achieve required values of mechanical properties of set concrete. This is an initial project that will be further modified and adapted to possibly monitor and evaluate concrete microstructures as an affecting factor of mechanical properties of concrete.

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