Cracks Width in The Middle of the Beam for Beams of Self-Compacting Concrete On the Long Term Process

Hajdar E. Sadiku[1], Berim Osmanaj[1], Durim Sadiku [1], Liridon Nalli [1]

ABSTRACT

Development trends for high rise constructions, modern skyscrapers indicate that building such constructions with normal concretes and low consistency is impossible, therefore there is a need for concrete with high processes because of great amount of reinforcement in cross-section of concrete elements. Solution for such construction is self-compacting concrete because of its ability to fill good formworks without compaction and vibration. Considering this fact, researches for cracks, mechanical characteristics of concrete and deformations have been conducted worldwide. In this line, we conducted an experimental research to determine the cracks on beams of self-compacting concrete and compared it with theoretical results on the middle of beam on long term process.

Keywords

Self-compacting concrete, conventional concrete, compression, cracks, modulus of elasticity

PREFACE

Self-compacting concrete like anywhere else in the world, as well as in Kosovo has been used widely in building construction, especially in high buildings and rehabilitation of existing facilities.

Under sustained loading, the propagation of cracks in concrete is assumed to be related to the elastic deformation, material parameters and time. Experiments have been performed on small concrete specimens to determine the cracking strain and to validate the finite element model. For flexural cracks, a creep coefficient model is adopted for bulk creep and a cracking strain rate based on test results is employed. For shear cracks fracture mode II is considered as well. The development of concrete strength in time is taken into account.

The tests showed that crack formation took place only some days after loading, but after a week the cracks stabilized and became dormant.

The tensile strength of concrete is about 10 percent of the compressive strength, but in the design of reinforced concrete structural elements, this strength is neglected. Steel reinforcement is provided to carry the tensile stresses in a member due to applied loads. It is expected that cracks will develop in a reinforced concrete member under service loads (the expected loads during the lifetime of the structure). However, the designer has some control over the width and distribution of structural cracks [2][3].

This publication aims to discuss the experimental findings self-compacting concrete by comparing their performances for modules of elasticity, compression strength and the size of cracks for beams during the duration testing time $t = 40$ days.

Diagram 1 presents the relative humidity and temperature during the research period in long term process [1].

Self-compacted concrete while in fresh conditions has a number of tests which can determine whether it can be used or not. We have only carried out three tests: J-ring, V-funnel and L-box. The following are the results obtained (EN 206-9, 2010):

- J ring h=7.5cm, d=57cm
- V funnel t_1=8.1s, t_2=9.48s
- U box h=40mm

The obtained temperatures of concretes were 25^{0}C for self-compacted concrete with the porosity values 1.8% for self-compacting concrete [1].

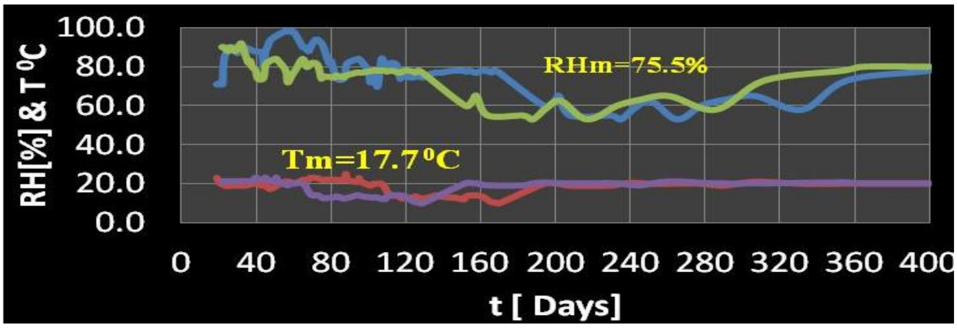
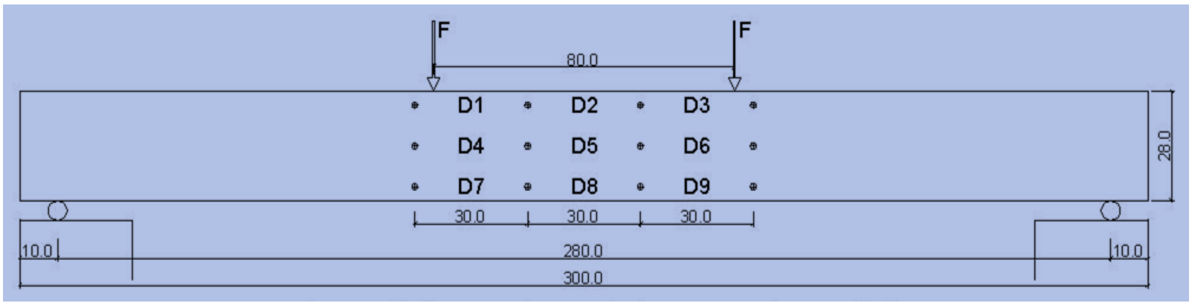


Diagram 1. Relative humidity and temperature on the experimental space

Concrete beam of self-compacted concrete

The static scheme is basically a simple beam loaded with two concentrated forces. The cross-section dimensions of beams are 15x28 cm, span of the beam is l=3m and are reinforced with two rebar's Φ12 in the tensile zone and two rebar's Φ8 in the compressing zone, figure 1. Process of the measurement of crack with and the measurement instruments is presented in figure 2. [1].



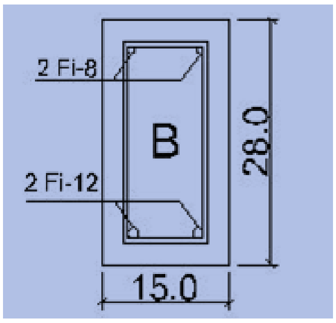


Fig. 1. Static scheme and cross-section of the beams [1].

Fig. 2. Measurement process of the crack with on the beams [1].

Cracking under bending moment

The first crack develops when tensile stress reaches tensile strength of the concrete at the zone of the greatest bending moment. This so called cracking moment (Mr) can be calculated as follows:

$$M\mathrm{r} = W\mathrm{cp}f\mathrm{ctk} \qquad (1)$$

where *Wcp* is the plastic flexural resistance for a rectangular cross-section when the effect of the reinforcement is not taken into account.

Creep and shrinkage

Creep is defined as increase in strain over time under the sustained constant stress, while shrinkage means decrease in volume with time. In steel-concrete composite structures, creep and shrinkage are highly associated with concrete, and these two inelastic and time-varying strains cause increase in deformation and redistribution of internal stresses **[3]**.

Since creep and shrinkage of concrete are too complicated to capture in any detail, many researchers have instead chosen to propose procedures that approximate the real phenomena but utilize more convenient methods to facilitate the design process. In this section, four existing models to predict creep and shrinkage that are in widespread use will be introduced, and the characteristics of each will be briefly described.

Drying shrinkage crack

Restrained shrinkage cracks can form through the fill depth of a member and thereby increase the permeability through the depth [2]. Cracks due to restrained drying shrinkage can be serious because, unlike flexural cracks, they can extend through the full depth of a member. The designer needs to consider these interactions to avoid undesirable full-depth cracks in critical structures, such as the containment for low level nuclear waste [2].

Experimental results

Assigned to the concrete mechanical characteristics are preparing a significant number of samples. They were to form, cubic, cylindrical and prismatic. A number of them are tested at age of concrete t=40 days and the rest at age of concrete t = 400 days.

In diagram 2 are presented the results of splitting tensile strength at age of concrete t=400 days while in diagram 3. are presented results of testing the elasticity module at age of concrete t = 400 days.

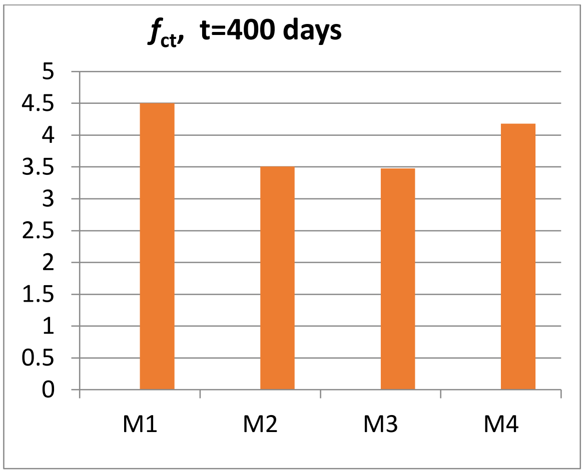


Diagram 2. Results of splitting tensile strength

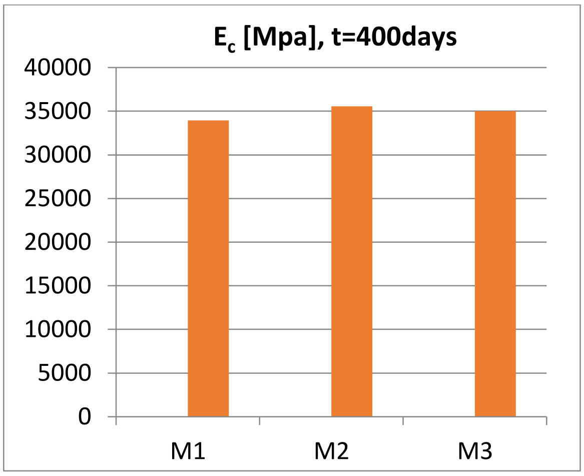


Diagram 3. Results Elasticity Module

In a long-lasting process two self-compacting beams of concrete were investigated for a duration of 400 days, during which time the concrete deformations, formwork deformations, beam cracking among the beams and the amount of cracking were measured. Table 1 presents the numerical values of the cracking width whereas diagram 4 shows its corresponding graphical results.

Table 1. Cracks with Results for thebeams of self-compacted concrete [1].

W-B			
t	mm	mm	mm
	B 5	***B 6***	**B**
40	0.00	0.00	0.00
40	0.02	0.02	0.02
100	0.12	0.08	0.10
200	0.16	0.12	0.14
300	0.16	0.12	0.14
400	0.16	0.12	0.14

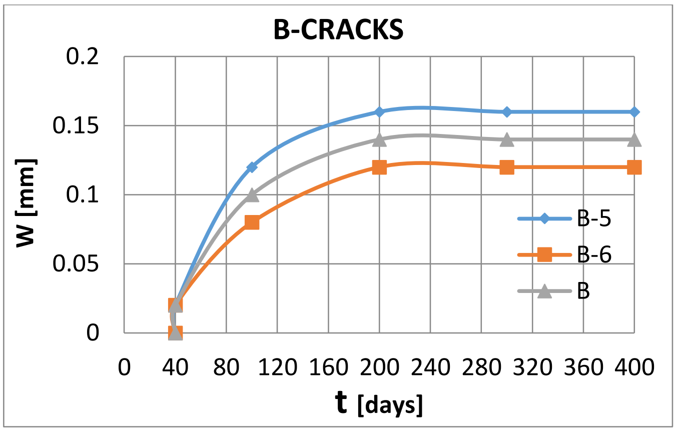
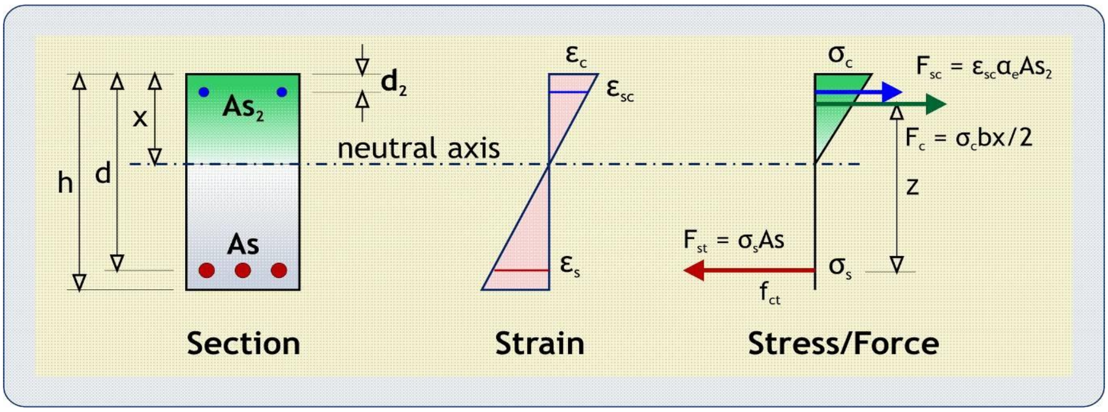


Diagram 4. Graphically results of crack width

Theoretical results

In order to compare experimental and theoretical results, the Eurocode 2 has been used to calculate the crack width in the middle of the beam. When calculated, it can be noticed that the crack width obtained when using Eurocode 2 is smaller than the one measured during the experiment.

Such a result is mainly due to the fact that self-contained concrete in itself contains amounts exceeding the aggregate fine grained in comparison with ordinary concrete, in this case, both, the tensile solidity and the module of elasticity are smaller.



f_{ck} =	30	MPa	Area of tension steel, **A** =	226	mm^2
f_{yk} =	500	MPa	**d** =	240	mm
b =	150	mm	Area of compression steel, **A** =	100	mm^2
h =	280	mm	**d₂** =	35	mm
QP moment, **M** =	9	KNm	Maxmum tension bar spacing, **S** =	78	mm
Age at cracking =	28	days	Max tension bar dia, **Ø_{eq}** =	12	mm
Cement type =	R	(S, N, R)	Short term or long term ?	L	(S L)
Creep factor, **φ** =	0.6		Cover to **A_{s,c}** =	25	mm

Modulus of elasticity of concrete = 22[(fck+8)/10]0.3	**E_{cm} =**	32.8	GPa
Modulus of elasticity of steel	**E_s =**	200.0	GPa
Modular ratio	**α_e =**	9.75	
Mean concrete strength at cracking	**$f_{cm,t}$ =**	38.00	MPa
Mean concrete tensile strength	**$f_{ct,eff}$ =**	2.90	MPa
Uncracked neutral axis depth	**x_u =**	142.36	mm
$[bh^2/2+(\alpha_e-1)(A_sd+A_{s2}d_2)]/[bh+(\alpha_e-1)(A_s+A_{s2})]$	**I_u =**	304	mm^4 10^6
Cracking moment = $f_{ct}I/(h-x)$	**M_{cr} =**	6.39	kNm
Fully cracked neutral axis depth $(-A_s\alpha_e-As2(\alpha e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{As\alpha ed-A_{s2}d2(\alpha e-1)\}]^{½})/b$	**x_c =**	68.24	mm
Concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$	**σ_c =**	7.505	MPa
Stress in tension steel = $\sigma_c \cdot \alpha_e(d-x)/x$	**σ_s =**	184.1	MPa
Effective tension area = min[2.5(h-d), (h-x)/3, h/2]b - A_s	**$A_{c,eff}$ =**	10362	mm^2
$A_s / A_{c,eff}$	**$\rho_{p,eff}$ =**	0.0218	
Max final crack spacing = min[1.3/(h-),3.4c+0.17Ø/$\rho_{p,eff}$)]	**$S_{r,max}$ =**	178.5	mm
Average strain for crack width calculation	**ε_{sm}-**	598.4	μ strain
Calculateded crack width	**W_k =**	**0.107**	mm

CONCLUSIONS

Based on the experimental findings it can be concluded that the contents of the grained aggregates reduces the tensile solidity and self-compacting resilience module.

The first cracking is presented by a smaller impact compared to that of the ordinary concrete and its size during the process of long-lasting load pressure, seems to be greater than theoretically calculated values (cracking).

The value of the crack size (crack width) is not theoretically the same when applied different standards like EC 2 ACI committee, etc.

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