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Crack Calculation of Beams from Self-Compacted Concrete

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Abstract*— *The latest developments of construction of high rise buildings like skyscrapers and different towers indicate that building such constructions with conventional concrete of low consistency is impossible due to the hard concreting process, mounting/demounting of scaffolding and the duration of concrete curing. Lately the most widely used material for construction of special buildings is self-compacting concrete because of the ability to fill entire section of formworks without compaction and vibration and better homogeneity between concrete and reinforcement. With massive usage of Self Compacted Concrete (SCC) in special buildings, series of researches are conducted all over the world analyzing cracks, mechanical characteristics and deformations of SCC.

These researches shows that calculation of concrete elements with normal concrete do not give adequate results according to EC2 because of the concrete class consistency and amount of reinforcement in the cross section. The SCC as raw material provides better results in term of concrete consistency gives better cross section homogeneity and it is vibration free. However SCC concrete cracks, deformations, creep, deflections are different than normal concrete and as such must be calculated and analyzed before application. In this paperwork we have presented calculation of cracks on long term process of SCC beam element after period of t=400 days from concreting and comparison of results with the theoretical ones in line with Eurocode 2 (EC2) requirements.

Keywords— *Conventional concrete, compression, cracks, modulus of elasticity, self-compacting concrete.*

I. INTRODUCTION

With appearance of new generate of admixtures (Super-plasticizers) the researcher Hajime Okamura presents for first time concrete which in regard to the content is different from the conventional concrete named this concrete as Self Compacted Concrete. Self-compacting concrete (SCC), also referred to as self-consolidating concrete, is a relatively new concrete technology that is used in the construction industry. It differs from normal compacting concrete (conventional mix design) in one key material property, it is able to flow under its own weight. Because of this material property, it is able to compact into every corner of the formwork, purely by means of its own weight and without the need for vibrating equipment (Ouchi, 2000:29).

SCC was first developed in 1988, in Japan. The material has since been applied for a multitude of reasons, as is the normal course of a new technology, but the high flowability is still the main advantage.

Self-compacting concrete (SCC) is defined as a concrete which is capable of self-consolidating without any external efforts like vibration, floating, poking etc. The mix is therefore required to have ability of passing, ability of filling and ability of being stable. Concrete is heterogeneous material and the ingredients having various specific gravity values and hence it is difficult to keep them in cohesive form. This is principally true when the consistency is too high. Super-plasticizers reduce water demand and at the same time increase fluidity. However, there is a probability of bleeding and mix may become adhesive. To overcome this problem viscosity-modifying agent (VMA) is required to be added. VMA is a pseudo plastic agent, which thickens the water and keeps the mixture under suspension, providing segregation resistance. The principle of sedimentation velocity is inversely proportional to the viscosity of the floating medium is appliedin the system. The intrinsic insufficiency of SCC as any other type of concrete is to defend against tension.

The term Self-Compacting Concrete (SCC) refers to a special type of concrete mixture, characterized by high resistance to segregation that can be cast without compaction or vibration. The material has been described as one of the most important developments in the building industry. It has also been noted that it (SCC) has the potential to dramatically alter and improve the future of concrete placement and construction processes.

The objective of this study is to compare cracks of SCC beam and make comparison with cracks from similar concrete conventional beam.

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For analyzing cracks of two types of concrete, trial of 6 concrete beams with SCC and another 6 conventional concrete beam was prepared. Instrumentation was installed on the beams before the transfer of stress to measure cracks. Camber monitoring started immediately after the transfer of stress and continued for 400 days from casting when the full collapse of concrete beam was done.

The intrinsic insufficiency of SCC as any other type of concrete is to defend against tension. In basic concrete the crack appears as soon as principal stresses increases the tensile strength of concrete and after the first crack immediately the collapse occurs. The inherent weakness of concrete to resist tension can be overcome to some extent by mixing the steel fibers in concrete or steel reinforcement. In our case steel reinforcement of beam was provided to carry the tensile stresses in a memberdue 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).

The laboratory conditions in term of relative humidity and temperature during the research period of long term process were: T_m=17.7^{0}C R_m=75.5% [3].

Rather, SCC test was performed As per EN 206-9, 2010 instructions with : [2], [3].

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

II. SELF-COMPACTED CONCRETE BEAM

The static scheme is assumed as simple supported beam with size 15x28 cm in cross section, and length of beam l= 3m, prestress with two concentrated forces and supports in distance l=2.8m, the flexural reinforcement in cross section of the beam is 2 Φ12 mm rather in compressing zone with 2 Φ8 mm. Long-term loading was performed by gravitational concrete elements weight. Recording was done from the first crack appearance in the concrete beam rather width was measured with microscope with a accuracy 0.02mm see, figure 1.

Process of cracks measurement and the measurement instrument is presented in figure 2.In figure 3Is presented measurement of crack width with microscope.

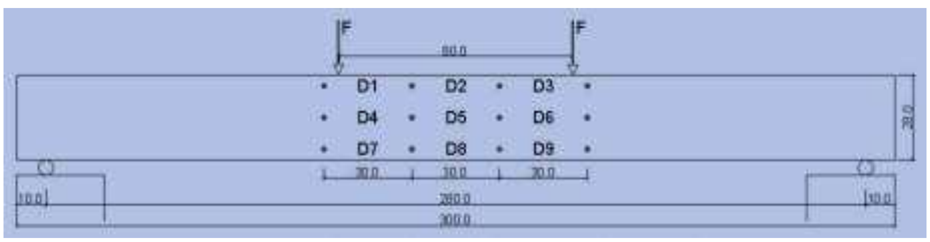

Fig. 1. Static scheme of the beam [3]

Fig.2: Measurement of the crack withand gravitationally load from concrete cerbs [3].

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Fig. 3a.: Measurement point of crack for long term proces[3]

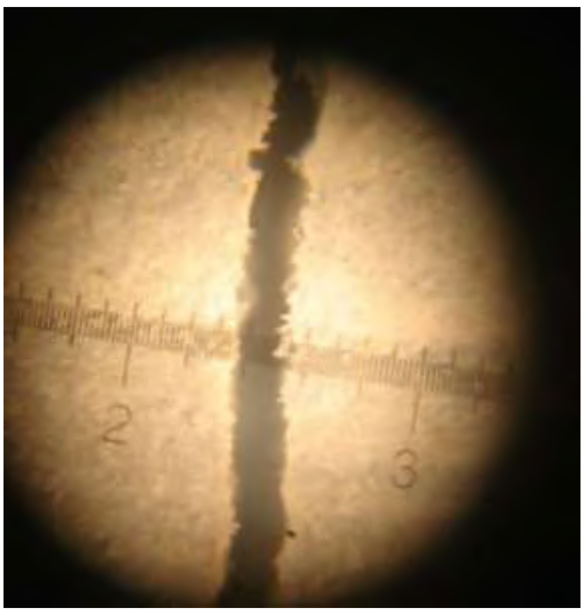

Fig. 3b: Crack width[3]

III. FORMATION OF CRACKS

Cracking as phenomena in the concrete beams is typical and cannot be avoided. Usually occurs in such parts of a concrete where tension stress reaches tensile strength. As it is known tensile stresses may be developed due to, external loading, imposed deformations or chemical reactions.

The cracks may be classified on the basis of their activeness, time of occurrence, their width and the components of building on which they are developed. According to EC 2 the surface width of crack should not exceed 0.3mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel, nor upon the durability of the structures. In the members where cracking in tensile zone is harmful either because they are exposed to moisture or in contact of soil or ground water, an upper limit of 0.2mm is suggested for maximum width of crack. For particularly aggressive environment such as the 'severe' category, the assessed surface width of crack should not in generally exceed 0.1mm.

However, cracking is not always detrimental to concrete. Crack spacing and crack width must be kept small enough by a proper design and construction of a structure. Therefore, the statically behavior, stability in use and appearance of the concrete structure is ensured. [6]

IV. TYPES OF CRACKS

Loading cracks-Types of loading cracks vary depending on the type of loading.

It is normally that some cracks will appear at points of maximum tensile stress of load level. If direct tension is applied to a concrete member, cracks are developing through the entire cross-section. Spacing of cracks in such cases is approximately 0,75 to 2 times the minimum thickness of the member. [6]

V. CRACKS UNDER BENDING MOMENT

This so called cracking moment (Mr) can be calculated as follows:

$Mr = W_{cp} * f_{ctk}$(1)

Where, Wcp is the plastic flexural resistance for a rectangular cross-section when the effect of the reinforcement is not taken into account [6].

Creep and shrinkage

Creepis defined as deformation of structure under sustained load. Basically, long term pressure or stress on concrete can make it change shape, while shrinkage means decrease in volume of concrete 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][8].

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. Inthis section, four existingmodels to predict creep and shrinkage that are in widespread use will be introduced, and the characteristics of each will be briefly described.[7]

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Drying shrinkage– is defined as the contracting of a hardened concrete mixture due to the loss of capillary water. This shrinkage causes an increase in tensile stress, which may lead to cracking, internal warping, and external deflection, before the concrete is subjected to any kind of loading. [2].

Shrinkage from drying is a part of the total strains in the concrette elements.

There ar two types of factors where affecting drying shrinkage:

Internal factors: mix design of concrete, aggregate(granulometry, forms, type of stons, with low absorbtion, ect),water content(mor water on the concrete mix higher shrinkage strains), type of admixtures.[9]

External factors: enveriomental conditions (temperature, relative humidity), compactions, plasing, dimensions of the cross sction of concrete elements, curing, ect. [9]

Fig. 3c: Beams treated on shrinkage[3]

Fig.3d: Strain measurement with mechanical strain gauge[3]

VI. FACTORS AFFESTING THE LONG-TERM CARCKS

Under sustained service loads, flexural cracks frequently form with time between the most widely spaced cracks in a cracked tensile region, thereby reducing the average crack spacing with time. In addition, flexural cracks frequently form with time in previously un-cracked regions thereby increasing extend of cracking [4].

VII. EXPERIMENTAL RESULTS

For determination mechanical characteristics of concrete, several trials and samples were prepared, the concrete samples were cubic, cylindrical and prismatic in accordance with EC 2, Some trials were tested at period of concrete t=40 days and the rest at period of concrete $t = \infty$.

Results are presented as following: in diagram 1 are presented results of splitting tensile strength f_{ct} for $t = \infty$, while in diagram 2, results of the Modulus of elasticity Ec for $t = \infty$.

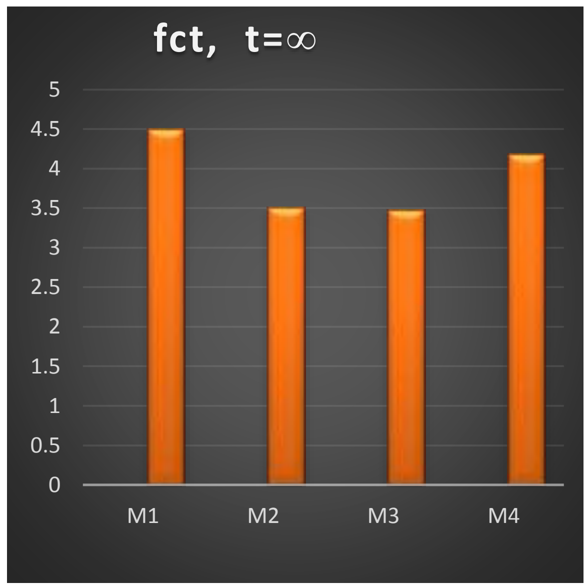

Diagram 2. Results of splitting tensile strength

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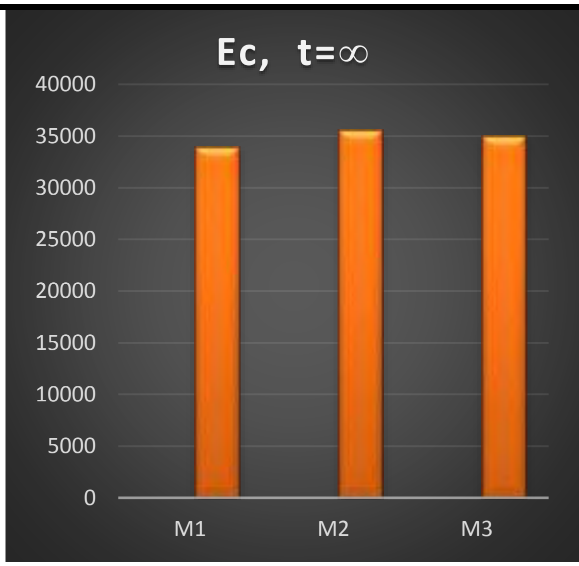
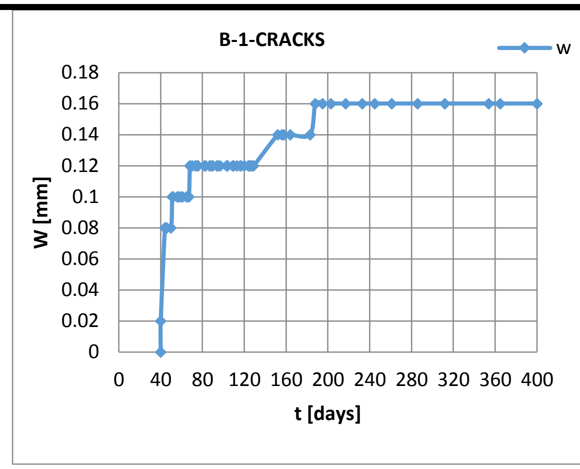


Diagram 3. Results Elasticity Module[3]

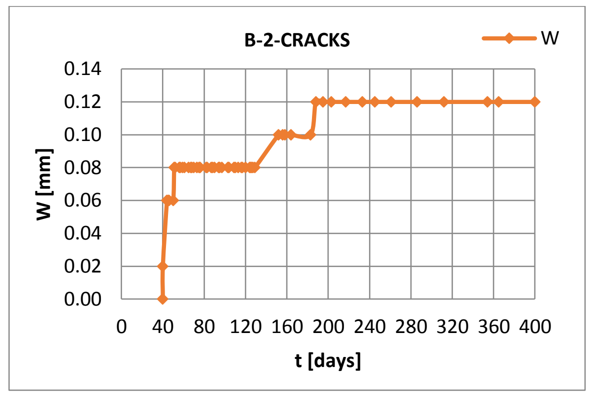
Table 1 presents the numerical values of the cracking width whereas diagram 4 shows its corresponding graphical results. The initial crack on beam B-1 occurs when we acting upon it with force of F=8kN thus causing the cracks width of w=0.08mm whereas the crack on beam B-2 occurs after acting upon it with F=7kN in which case, the cracks width will be w=0.06mm.

Table.1: Results for Cracks with the beams of self-compacted concrete [3]

W-B			
t	mm	mm	mm
	B 1	*B 2*	B
40	0	0	0.000
40	0.07	0.06	0.065
100	0.12	0.08	0.100
200	0.16	0.12	0.140
300	0.16	0.12	0.140
400	0.16	0.12	0.140



a)



b)

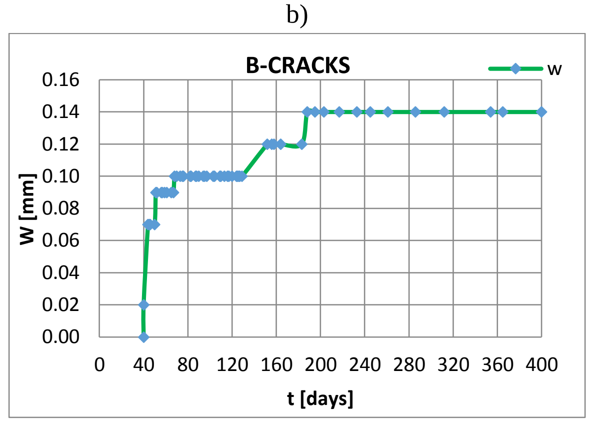


Diagram 4.Crack width for SCC beams[3]

VIII. THEORITICAL RESULTS

Middle beam cracks analysis was done according to EC 2 model for comparing theoretical and experimental results. It has been noticed that EC 2 gives lower values of cracks than thus obtained by trial. This difference is mainly due to the reason that SCC contains more percentage of fine particles than conventional concrete. Tensile solidity and the module of elasticity have lower values as well. [5].

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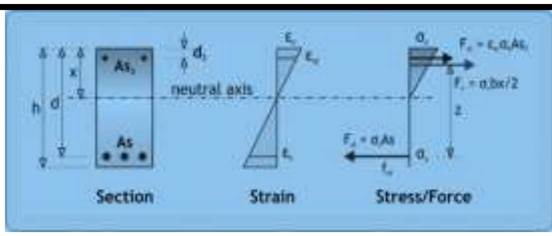

Fig.4: Strains in beam

INPUT DATA

fck =	30	MPa	A_{s1} =	226	mm²
fyk =	500	MPa	d =	128	mm
b =	150	mm	A_{s2} =	100	mm²
h =	280	mm	d_2 =	32	mm
M =	9.2	KNm	S =	76	mm
Age =	28	days	Øeq =	12	mm
Cement =	R			L	L
ϕ =	0.7		As, c =	25	mm

OUTPUT DATA

Mcr =	6.41	kNm
→ section is CRACKED		
$s_{r,max}$ =	178.2	mm
$\varepsilon_{sm}-\varepsilon_{cm}$ =	619.4	μ_{strain}
Wk =	0.110	mm

IX. CONCLUSIONS

Based on the experimental findings it can be concluded that the contents of the grained aggregates reduces the tensile solidity and self-compacting concrete Modulus of Elasticity. First cracks under ultimate loading appears early in SCC than in conventional concrete beams. Final results of crack width for period t=400 with trial were slightly higher than the results calculated with EC 2.

Difference between trial and theoretical results differed in range of approximately 30%.

International standards for calculation of crack width gives different results and as such are not unified. The Designer must consider this difference.

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