INFLUENCE OF LOADING SPEED TO THE STRENGTH CLASS OF STEEL FIBRE CONCRETE BY THE FOUR POINT TEST ARRANGEMENT

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Abstract

Inconsistent methodology for evaluating of the strength class of SFC (steel fibre concrete), and also various possibilities of testing to obtain strength classes give large variance of results to designers.

The main goal of this paper is to show the differences in strength classes on identical samples by the four-point test arrangement, with a different speed of loading (0,5 mm/min and 0,2 mm/min).

Classification into the strength classes of SFC is according to recent methodology TP-FC 1-1, as temporary materials before issuing the new European standards.

Strength properties of SFC were verified on standard samples. Compressive strength was verified on cubes (150 mm), tensile strength was verified on beams (150/150/700 mm) by four point bending test.

Keywords: strength class, steel fibre concrete (SFC), loading speed, TP-FC 1-1

1. Introduction

The increasingly frequent application of steel fibre concrete in the manufacture of construction elements of steel fibre concrete, or steel fibre concrete constructions leads to a need to address the question of strength classes of steel fibre concrete. Only the characteristic strengths of SFC based on material testing and putting into the strength classes of SFC provide the reliability of the designed SFC constructions implemented in the future.

At present, there is still no uniform procedure in material testing and method of deriving important characteristic strengths of manufactured steel fibre concrete. Regulations the

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main manufacturers, such as Bekaert, Krampe-Harex, etc. apply own procedures how to describe manufactured SFC including the static design of SFC constructions.

The main differences in these regulations are reflected in the disparately arrangement of material testing, especially those which characterize tensile strengths of SFC. It also use of laid down tensile characteristics after the formation of macro-crack in the design of SFC constructions based on the test is not uniform. Disunity stays in loading speed of beams during the bending test, too. From these tests are derived tensile strengths for static design of SFC construction.

This contribution summarizes in the tab. 1. - 3. characteristics of the two type of steel fibre concrete, which differed only by the type of used steel fibre, thus Dramix RC-80/60-BN and Tri-Treg length of 50 mm of diameter 1,05 mm. Composition of the concrete matrix was left the same. Material tests for the strength SFC in compression were performed on cubes 150 mm, bending tests on the beams of dimensions 150/150/700 mm by the four-point loading arrangement at the margin of 600 mm. Bending tests were carried at two speed of loading, thus 0,2 mm/min and 0,5 mm/min.

2. Characteristics of the tested SFC

For clarity, the results of the tests, strength calculation and classification of tested steel fibre concrete divided into 3 tables. Table 2. for compressive strength according to the used steel fibres and Table 3. for tensile strength, which the most characterize manufactured SFC.

Labeling partial strength, the way the tests performed, and the classification of SFC into the appropriate strength classes are in accordance with TP-FC 1-1, which have been processed at Czech Technical University in Prague, Faculty of Civil Engineering, Department of Concrete and Masonry Structures as a basis usable until the edition of European standards.

These standards not only unify the principles for determination of SFC strength classes, as well as procedures for testing these SFC samples and also in the design SFC constructions.

Tab.1: The results of pressure tests on SFC samples with 70 kg/m^3 steel fibres Dramix and Tri-Treg

Sample number	Dimensions			Weight [g]	Bulk density [kg/m^3]	Compressive force [kN]	$f_{fc,\,cub}$ [MPa]	
	b [mm]	h [mm]	l [mm]					
SFC: The term of tests: 7.12.2010								
1	151,2	153,8	150,3	8581	2455	2008	86,3	Dramix
3	151,9	154,1	150,7	8602	2439	1889	80,7	
5	150,5	155,3	150,8	8529	2420	1615	69,1	
Average value $f_{fc,mc,cub}$:							78,7	
SFC: The term of tests: 16.12.2010								
1	152,8	153,2	150,0	8482	2416	1936	82,7	Tri-Treg
3	151,0	153,0	151,1	8520	2441	2038	88,2	
5	149,7	154,7	150,5	8503	2440	1820	78,6	
Average value $f_{fc,mc,cub}$:					2432		83,2	

Tab.2: Pressure characteristics – Dramix RC-80/60-BN / Tri-Treg

Dramix RC-80/60-BN - 70 kg	Loading speed	
	0,2 mm/min	0,5 mm/min
Average cube strength $f_{fc,mc,cub}$ [MPa]	78,70	
Standard deviation of three samples $k_{s,3}$ [-]	8,77	
The characteristic scattering $\Delta f_{ck,\ cub,\ 3}$ [MPa]	8,77 * 1,89 = 16,58	
The characteristic cube strength $f_{fc,\ ck,\ cub}$ [MPa]	78,70 - 16,58 = 62,12	
The next lower characteristic cube strength class according to TP-FC 1-1, tab 2.7.1b $f_{fc,\ ck,\ cub}$ [MPa]	60	
FC $f_{fc,\ ck,\ cyl}$ / $f_{fc,\ ck\ ,cub}$ Considering the ratio 0,9	FC 55/60	

Tri-Treg - 70 kg	Loading speed	
	0,2 mm/min	0,5 mm/min
Average cube strength $f_{fc,mc,cub}$ [MPa]	83,20	
Standard deviation of three samples $k_{s,3}$ [-]	4,82	
The characteristic scattering $\Delta f_{ck,\ cub,\ 3}$ [MPa]	4,82 * 1,89 = 9,11	
The characteristic cube strength $f_{fc,\ ck,\ cub}$ [MPa]	83,20 - 9,11 = 74,09	
The next lower characteristic cube strength class according to TP-FC 1-1, tab 2.7.1b $f_{fc,\ ck,\ cub}$ [MPa]	67	
FC $f_{fc,\ ck,\ cyl}$ / $f_{fc,\ ck\ ,cub}$ Considering the ratio 0,9	FC 60/67	

Tab.3: Tensile characteristics – Dramix RC-80/60-BN / Tri-Treg

Dramix RC-80/60-BN 70 kg	Loading speed	
	0,2 mm/min	0,5 mm/min
Limit for macro-cracks $\delta_{t,cr}$		
Average resistance $F_{Rm,cr}$ [KN]	35,43	41,90
Standard deviation σ_{n-1} [-]	0,50	3,75
The characteristic scattering $\Delta F_{k,cr}$ [KN]	0,94	7,10
The characteristic resistance $F_{rk,cr}$ [KN]	34,49	34,80
Characteristic moment $M_{Rk,cr} = 0{,}1 * F_{Rk,cr}$ [KNm]	3,45	3,48
Characteristic tensile strength in bending $f_{fc,tk,fl} = 6 * M_{Rk,cr} / bh^2$ [MPa]	6,13	6,19
Characteristic central tensile strength $f_{fc,tk,cr} = f_{fc,tk,fl} / 1{,}45$ [MPa]	4,23	4,27
Central tensile strength class according to TP-FC 1-1, tab. 2.7.2 $f_{fc,tk}$ [MPa]	4,20	4,20

Tri-Treg - 70 kg	Loading speed	
	0,2 mm/min	0,5 mm/min
Limit for macro-cracks $\delta_{t,cr}$		
Average resistance $F_{Rm,cr}$ [KN]	36,30	47,91
Standard deviation σ_{n-1} [-]	2,63	1,65
The characteristic scattering $\Delta F_{k,cr}$ [KN]	5,29	3,33
The characteristic resistance $F_{rk,cr}$ [KN]	31,01	44,58
Characteristic moment $M_{Rk,cr} = 0{,}1 * F_{Rk,cr}$ [KNm]	3,10	4,46
Characteristic tensile strength in bending $f_{fc,tk,fl} = 6 * M_{Rk,cr} / bh^2$ [MPa]	5,51	7,93
Characteristic central tensile strength. $f_{fc,tk,cr} = f_{fc,tk,fl} / 1{,}45$ [MPa]	3,80	5,47
Central tensile strength class according to TP-FC 1-1, tab. 2.7.2 $f_{fc,tk}$ [MPa]	3,80	5,40

Tab.3: Tensile characteristics – Dramix RC-80/60-BN / Tri-Treg - continuation

Dramix RC-80/60-BN 70 kg	Loading speed 0,2 mm/min	Loading speed 0,5 mm/min
Agreed limit deflection $\delta_{t,3,5}$ = 3,5 mm		
Average residual strength $F_{Rm,res1}$ [KN]	26,86	20,94
The characteristic scattering ΔF_{Rk} [KN]	5,85	3,86
Residual characteristic resistance $F_{Rk,res,1}$ [KN]	21,01	17,08
Characteristic moment $M_{Rk,res,1} = 0,1 * F_{Rk,res,1}$ [KNm]	2,10	1,71
Equivalent characteristic strength in central strength $f_{fc,tk,eq,1} = 2,2 * M_{Rk,res,1} / bh^2$ [MPa]	1,37	1,11
Strength class in central strength at δ_t = 3,5 mm according to TP-FC 1-1, tab. 2.7.3 $f_{fc,tk,1}$ [MPa]	1,20	1,10
Strength class of SFC FC $f_{fc,ck,cyl}/f_{fc,ck,cub} - f_{fc,tk,cr}/f_{fc,tk,eq}$	FC 55/60 - 4,20/1,20	FC 55/60 - 4,20/1,10

Tri-Treg - 70 kg	Loading speed 0,2 mm/min	Loading speed 0,5 mm/min
Agreed limit deflection $\delta_{t,3,5}$ = 3,5 mm		
Average residual strength $F_{Rm,res1}$ [KN]	14,01	30,93
The characteristic scattering ΔF_{Rk} [KN]	3,10	1,09
Residual characteristic resistance $F_{Rk,res,1}$ [KN]	10,91	29,84
Characteristic moment $M_{Rk,res,1} = 0,1 * F_{Rk,res,1}$ [KNm]	1,09	2,98
Equivalent characteristic strength in central strength $f_{fc,tk,eq,1} = 2,2 * M_{Rk,res,1} / bh^2$ [MPa]	0,71	1,95
Strength class in central strength at δ_t = 3,5 mm accordind to TP-FC 1-1, tab. 2.7.3 $f_{fc,tk,1}$ [MPa]	0,60	1,00
Strength class of SFC FC $f_{fc,ck,cyl}/f_{fc,ck,cub} - f_{fc,tk,cr}/f_{fc,tk,eq}$	FC 60/67 - 3,80/0,60	FC 60/67- 5,40/1,00

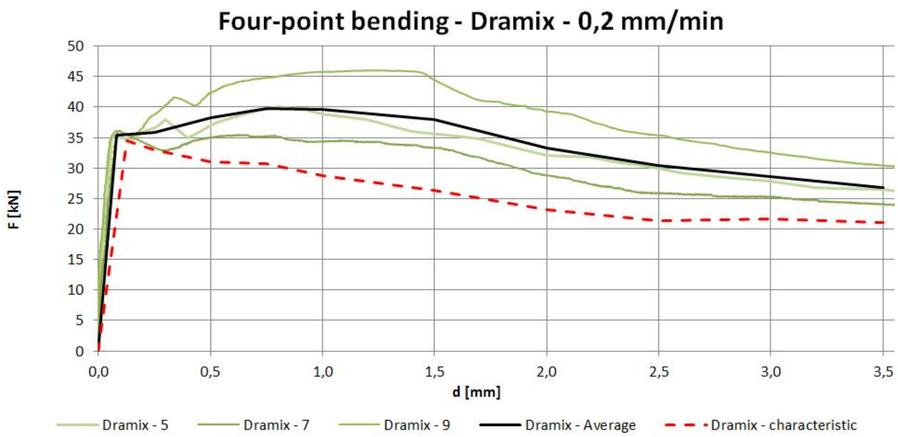

Fig. 1: SFC with Dramix steel fibre at speed loading 0,2 mm/min

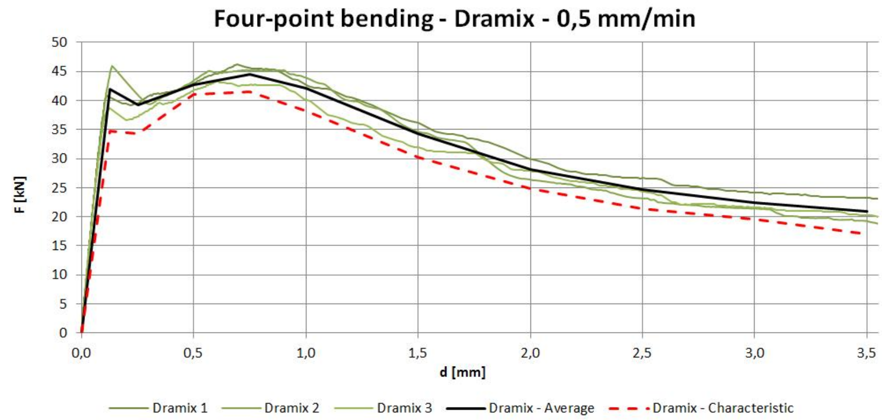

Fig. 2: SFC with Dramix steel fibre at speed loading 0,5 mm/min

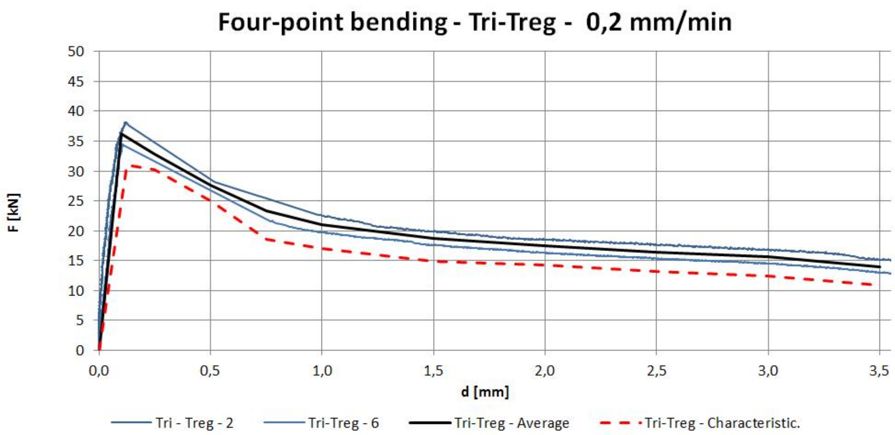

Fig. 3: SFC with Tri-Treg steel fibre at speed loading 0,2 mm/min

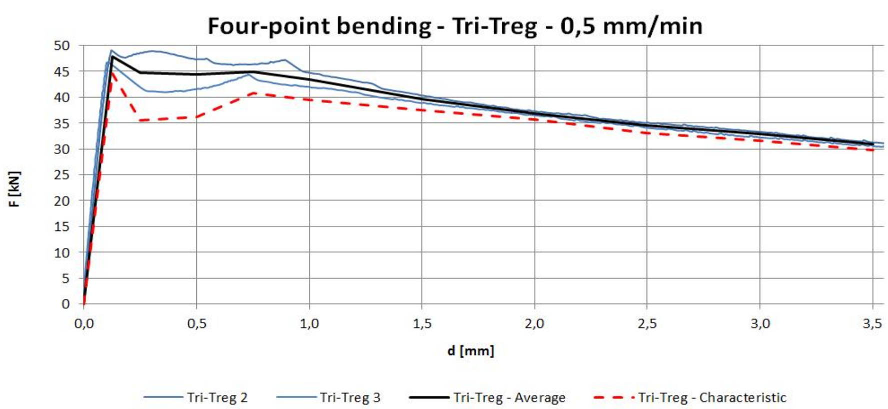

Fig. 4: SFC with Tri-Treg steel fibre at speed loading 0,5 mm/min

For clarity, the following figures (fig.5 – fig.6) display the average work (energy), that needs to be done to achieve the ultimate deflection of beam of 3,5 mm.

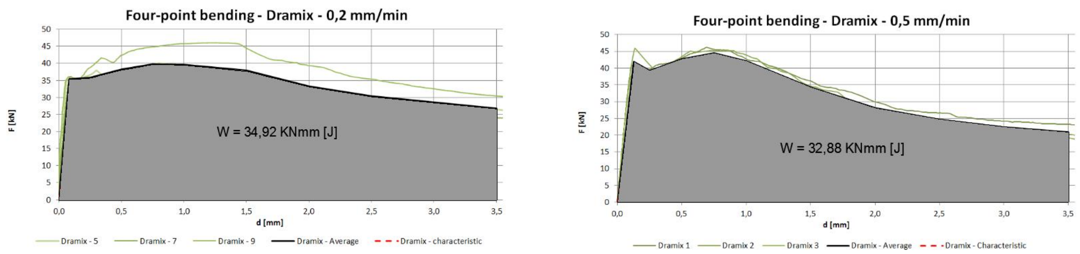

Fig. 5: SFC with Dramix steel – show the average work to achieve the ultimate deflection of 3,5 mm

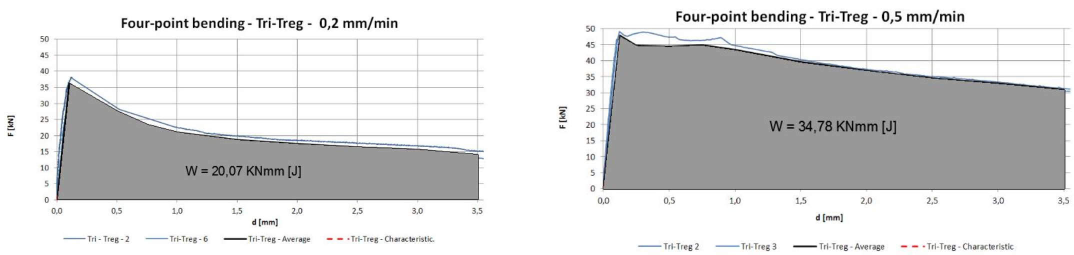

Fig. 6: SFC with Tri-Treg steel – show the average work to achieve the ultimate deflection of 3,5 mm

3. Discussion to these results

3.1 Compressive strengths

Differences between measured compressive strengths can be attributed to a greater dispersion of test results that showed Dramix steel fibres, when at the same weight dosage of steel fibres in the structure of steel fibre concrete is twice the number of steel fibre compared to SFC with the use of Tri-Treg steel fibres. Consideration should be given to the number of testing samples.

3.2 Tensile strengths

Assessment of test results between the two SFC was based on loading speed on bending tests. In any case, the results of these tests confirmed the fact, that increased speed results in achieving higher strengths. Even here, in the case of bending tests showed structures of SFC similarly to the pressure test and only in cases testing by the speed of 0,5 mm/min. In the case of tensile strengths acquired during the loading speed 0,2 mm/min is the opposite result. This fact can be attributed to the structure of SFC with a larger number of Dramix steel fibres, but with the note, that the number of 3 samples is not fully conclusive.

4. Conclusion

Stated strength classes tested SFC, which are differing only in the type of using steel fibres, showing the real differences measured tensile strengths by the bending test at the speed loading 0,2 mm/min and 0,5 mm/min.

It necessary to mention the fact, that the tests were conducted in one testing laboratory in Klokner Institute of the Czech Technical University in Prague. An example of processing the results of material tests see the table 1. – 3., which should be an instructions to an assessment of the basic characteristics of the proposed SFC before their using in load-bearing constructions. Only this way, from the shown characteristics can be based structural engineer designing SFC structures.

Labeling partial strength characteristics of SFC and the resulting strength classes, which was performed according to the TP FC 1-1, as a temporary document before issuing the European standards should be used to discussions the professional public, as how denote strength classes of SFC – only C (concrete), or FC (fibre concrete), or FRC (fibre reinforced concrete). Discussion can continue relating to the labelling sequence characteristic strengths. Recommended labelling strength classes of SFC according to TP-FC 1-1 follows directly from the tables.

Acknowledgements

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