BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
Department of Mechanics, Materials and Structures
Laboratory of Materials and Structures

EUROPEAN FIBRES
FRC beam test series

SYNTHETIC MACRO FIBER REINFORCED BEAMS RESEARCH

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1. Introduction

The goal of this research was to test independently the leader synthetic fibres in the European market. Most of the fibres are used for industrial floors, tunnels or precast concrete elements. For this reason we tested from two different concrete strength class: C30/37 and C50/60, the first modelled the typical industrial floor concrete, and the second the typical precast or tunnel.

The beams was made in the same circumstances, e.g. same day from the same kinds of concrete and tested at the same time. During the hardening phase all the beams was stored in the same conditions.

2. Testing specimens

2.1. Geometry

The test beam specimens measured 600 mm long with a section of 150 x 150 mm. The beams were notched on the bottom to a thickness of 3 mm and 25 mm depth, the loading was applied above the notch.

Test specimens were made at the concrete laboratory of MAPEI on 4-8 of February, 2013.

The beams was named according to the fiber and the dosage, i.e. BC48 5kg.

2.2. Concrete

Two kind of concrete was made: C30/37 and C50/60. Both mix has a flow and a slump tests by plain concrete and fibre reinforced concrete.

Fig 1. flow test and slump test of the plain concrete

The exact mix properties can be found in Annex A.

2.3. Fibres

The name of the fibres, photos and documents are set out in the results section. The geometry of the fibre, shape, material and the notes during the mixing (i.e. any mixing problems) are also stated.

3. Test method

The testing method is as stated in Fig. 2.

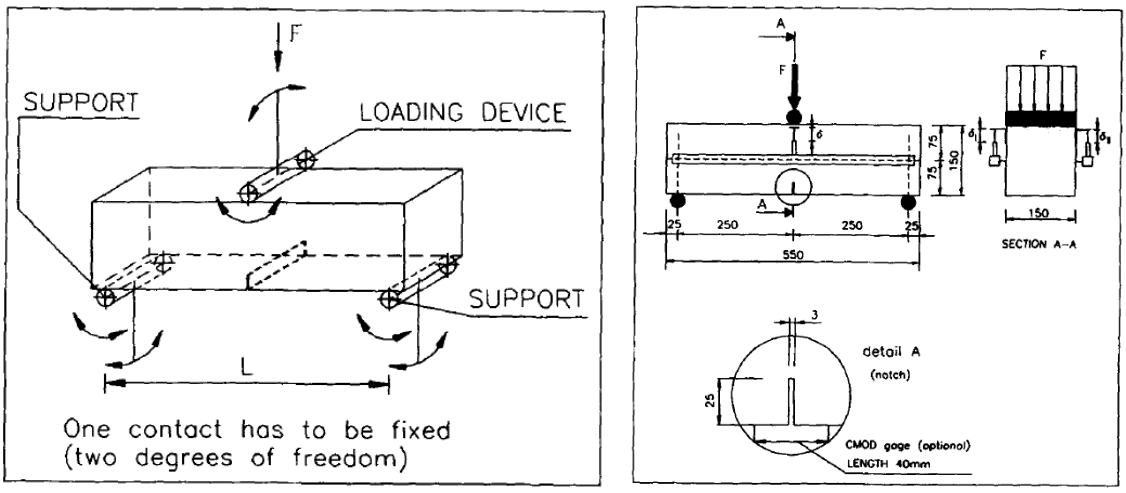


Fig. 2.: testing method recommended by RILEM

We made the test according to the following guideline:
RILEM TC 162-TDF : Test and design methods for steel fibre reinforced concrete (Vandewalle, L., et al., 2002).

3.1. R_{e3}

The most suitable design recommendation for designing industrial floors is the TR34 – Concrete industrial ground floors (The Concrete Society UK, 2003). The use of the R_{e3} number for designing FRC floors is defined in the Japanese guideline JSCE SF-4 (Japanese Society of Civil Engineers, 1985). The R_{e3} number is the average of the residual stress and the flexural strength divided in percentage (Fig. 3.):

$$R_{e3} = \frac{F_a}{F_c}(\%)$$

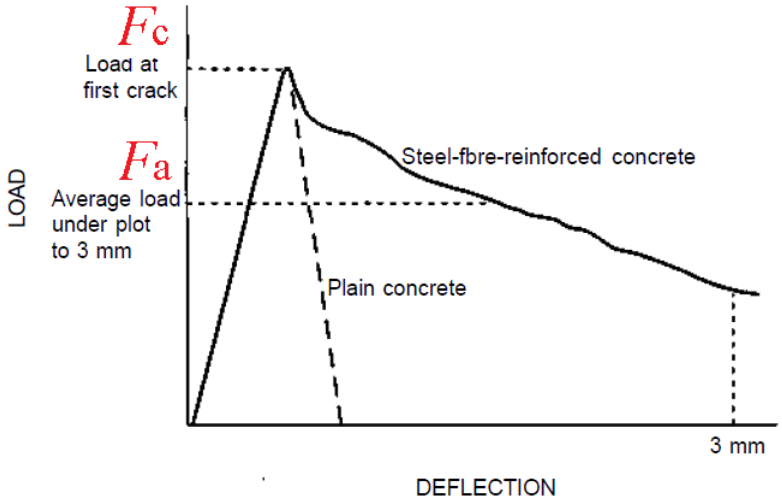


Fig. 3.: the calculation of the residual stress (JSCE SF-4)

3.2. Load-deflection and load-CMOD diagrams

Most of the guidelines use the load-deflection diagram to define the stress-strain diagram, but there are also some that prefer the load-CMOD (Crack Mouth Opening Displacement). This value is directly measured on the crack opening, whist the stress-strain diagram could be defined more accurately.

Both measurement is suitable for calculation and for comparing different kind of FRC.

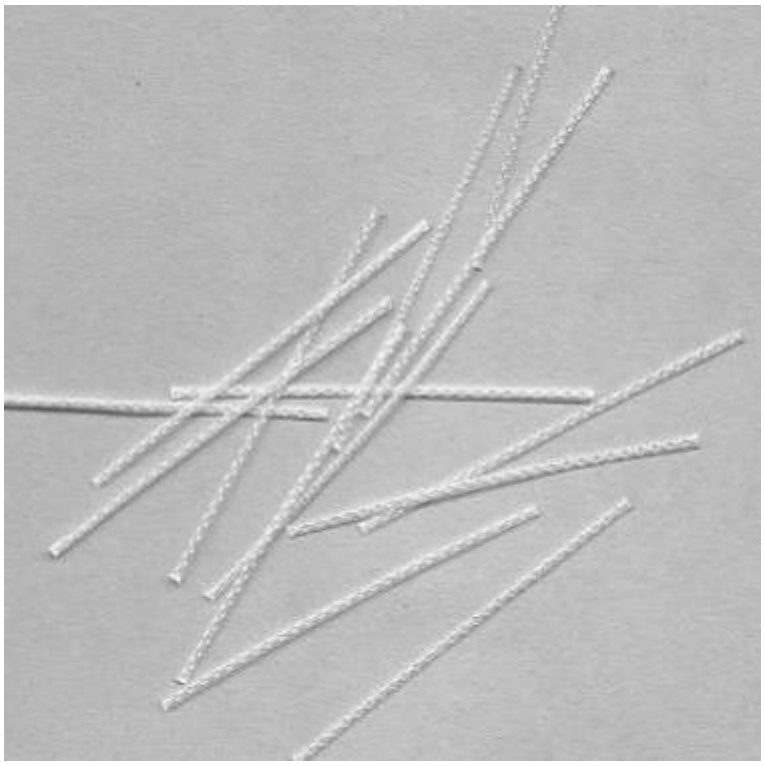
4. Results
4.1. MAKRO1 – EPC BC48 – dosage 4 kg and 6 kg

Details of the fibre

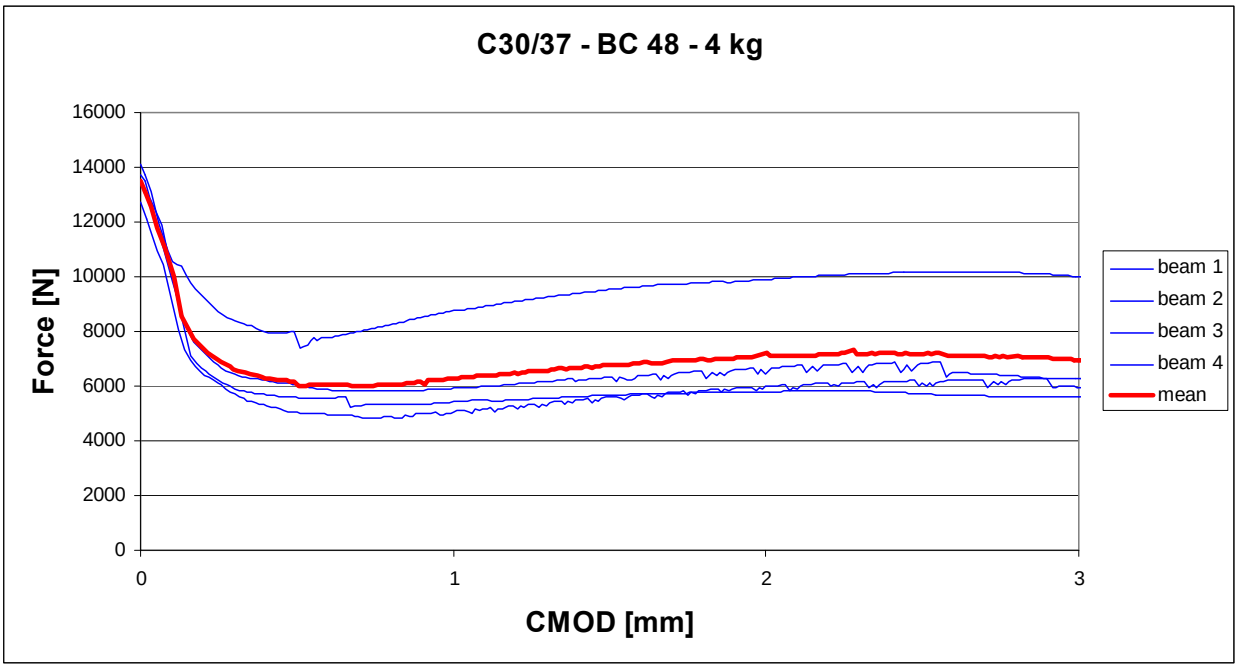
type:	embossed surface polypropylene fibre	
section:	oval	
length:	48 mm	
diameter:	1,3 x 0,5 mm	
weight:	1,66 gram / 100 db	
number in 1 kg:	60241	
dosage:	4 kg/m^3	6 kg/m^3
volume%:	0,6939 m^3/m^3	1,0409 m^3/m^3

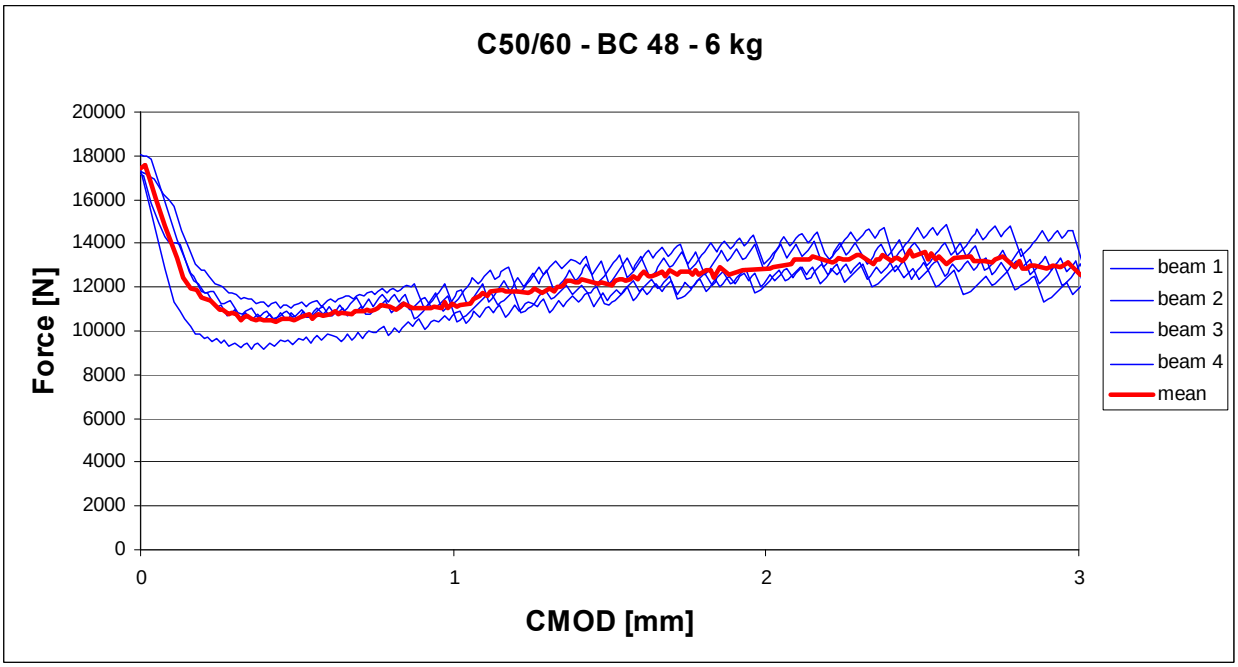
Notes

The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.



Load-CMOD diagrams





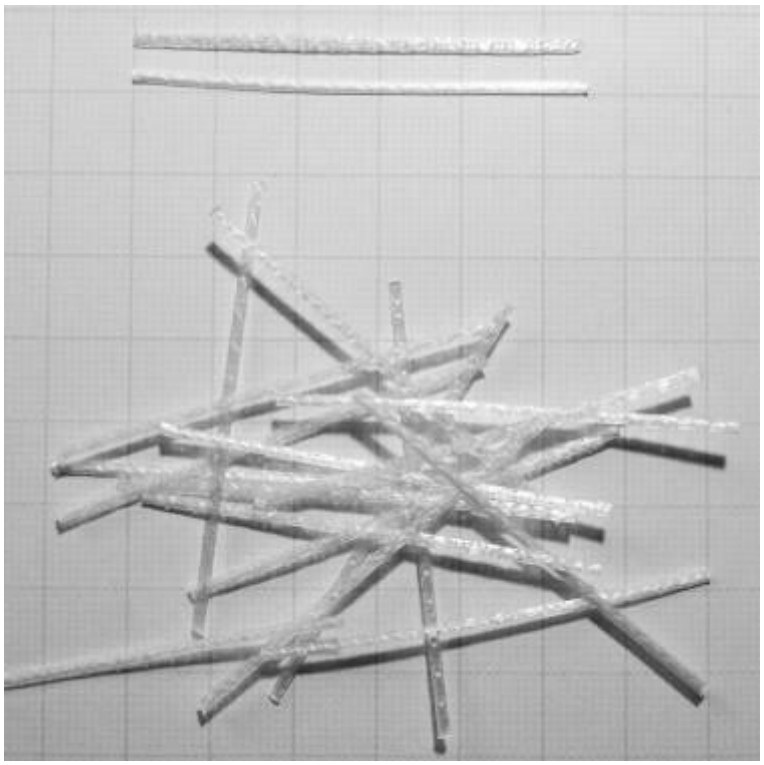
4.2. MAKRO2 – EPC BC54 – dosage 4 kg and 6 kg

Details of the fibre

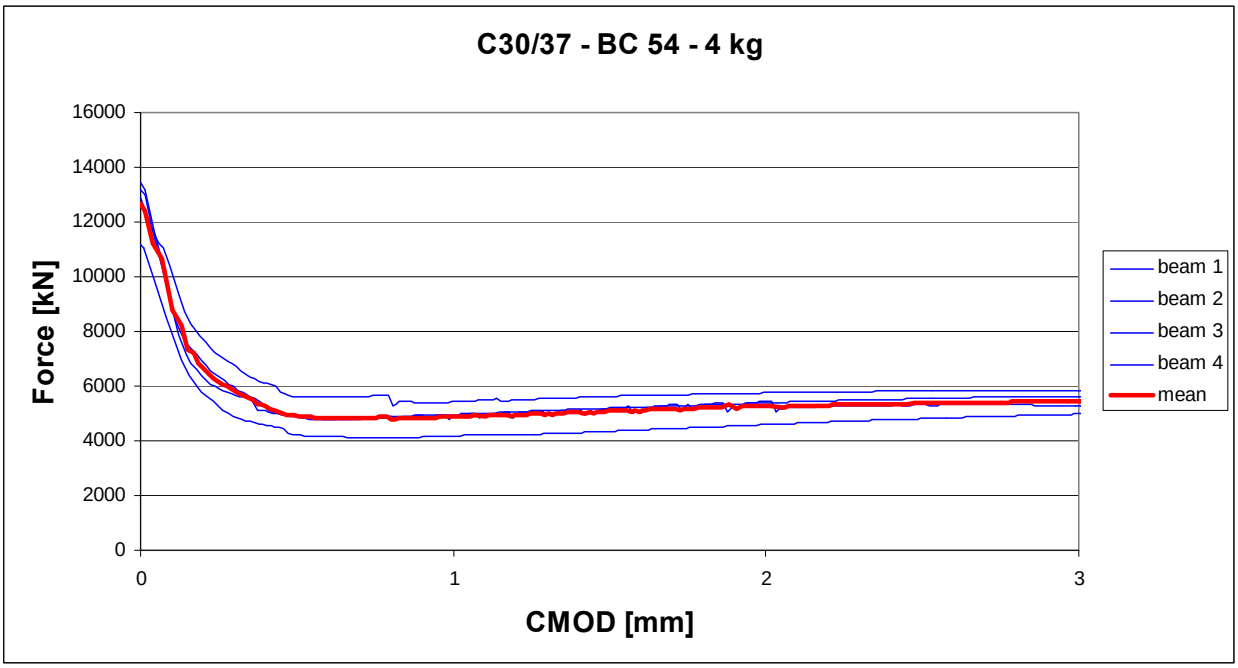
type:	embossed surface polypropylene fibre	
section:	oval	
length:	54 mm	
diameter:	1,4 x 0,4 mm	
weight:	2,81 gram / 100 db	
number in 1 kg:	35587	
dosage:	4 kg/m^3	6 kg/m^3
volume%:	0,4304 m^3/m^3	0,6456 m^3/m^3

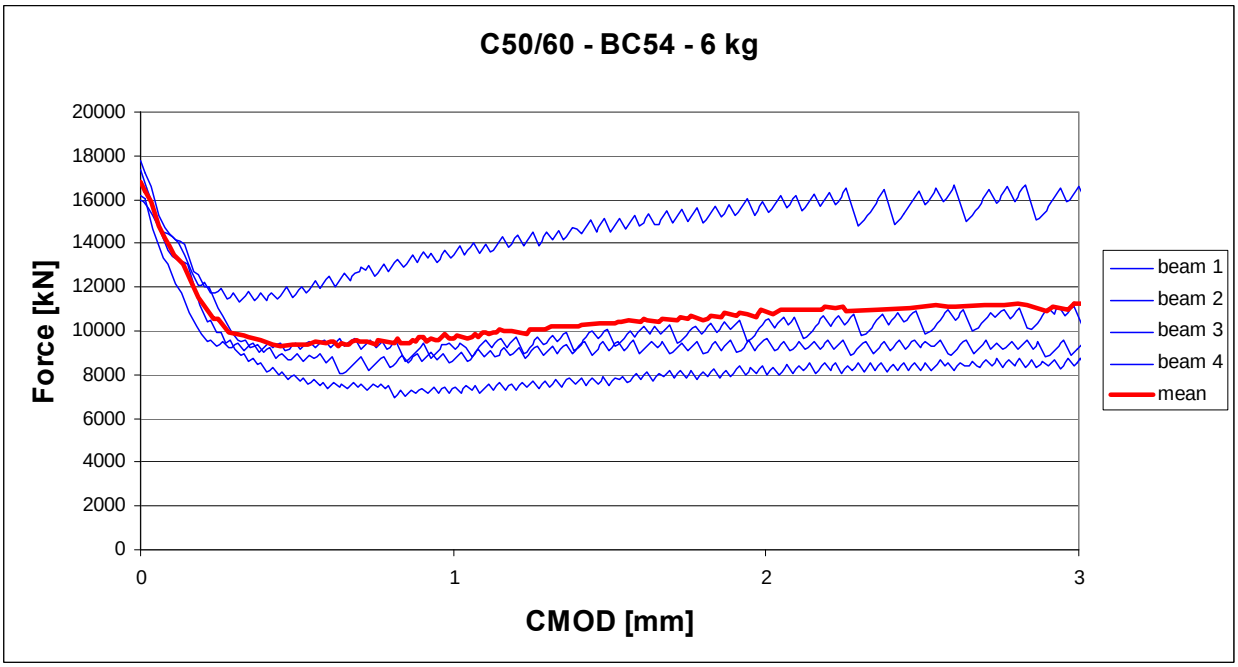
Notes

The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.



Load-CMOD diagrams





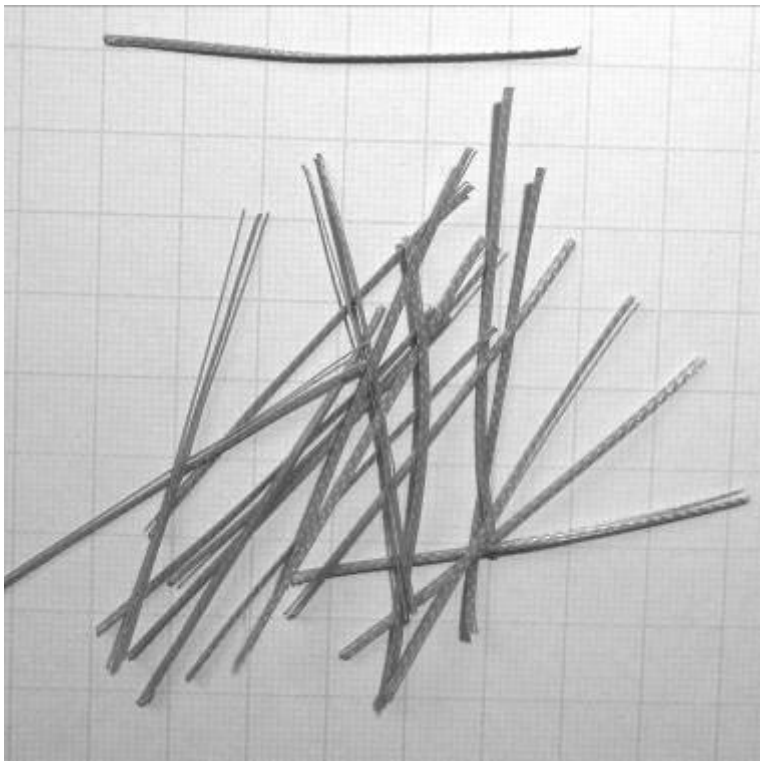
4.3. MAKRO3 – EPC MQ58 – dosage 4 kg

Details of the fibre

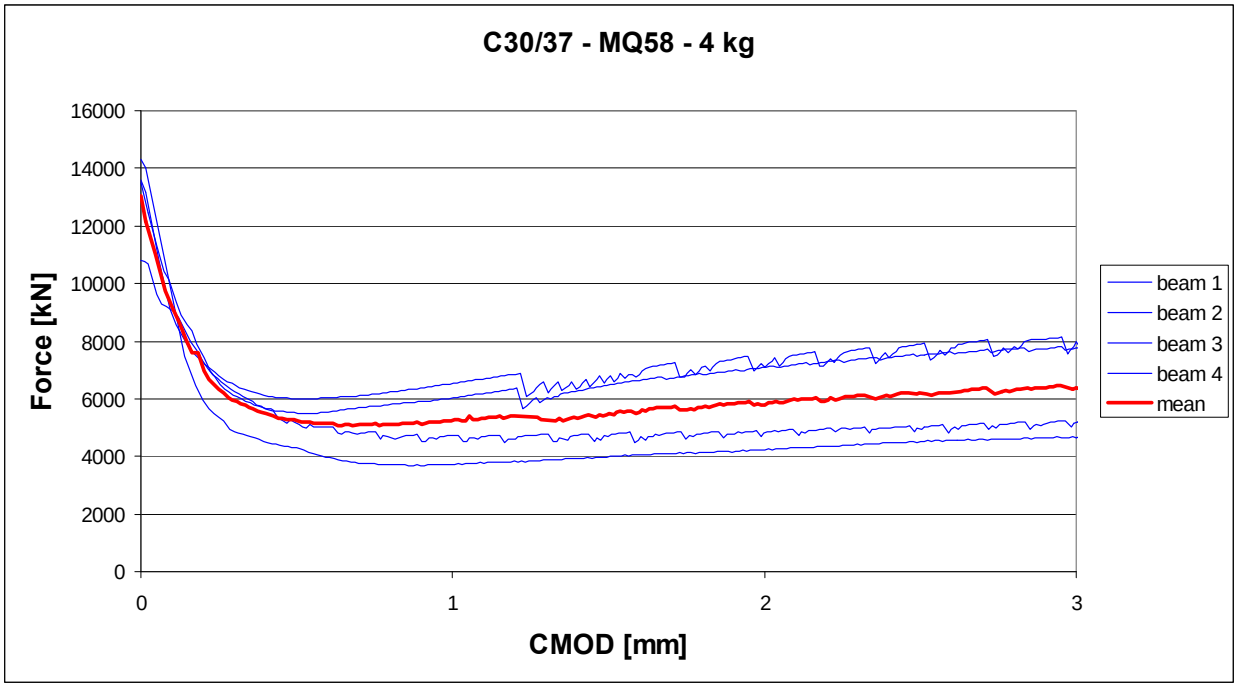
type:	embossed surface polypropylene fibre
section:	oval
length:	58 mm
diameter:	0,4 x 1,1 mm
weight:	1,96 gram / 100 db
number in 1 kg:	51020
dosage:	4 kg/m^3
volume%:	0,5208 m^3/m^3

Notes

The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.



Load-CMOD diagrams



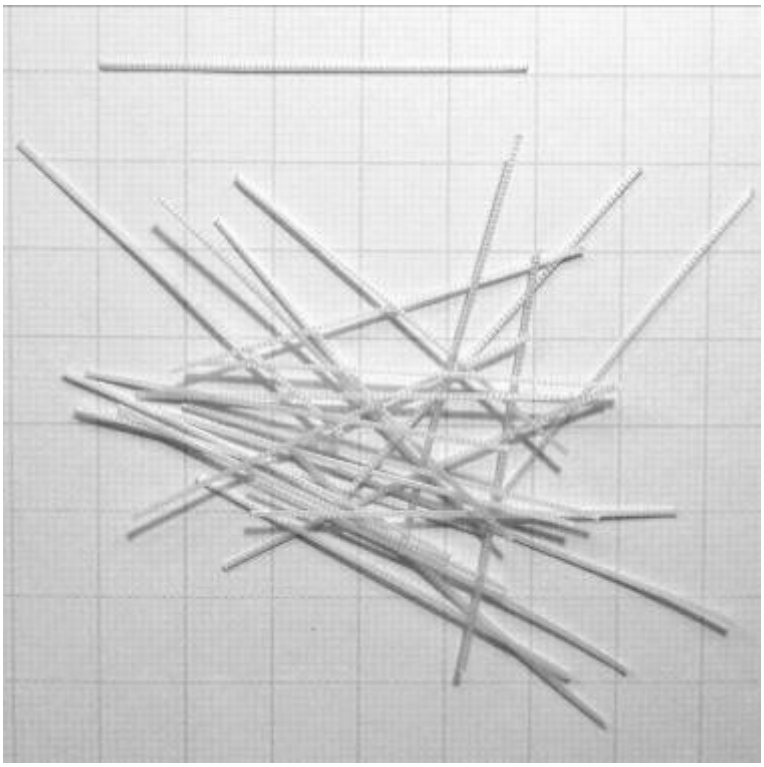
4.4. MAKRO4 – BRUGG CONTEC CONCRIX – dosage 4 kg and 6 kg

Details of the fibre

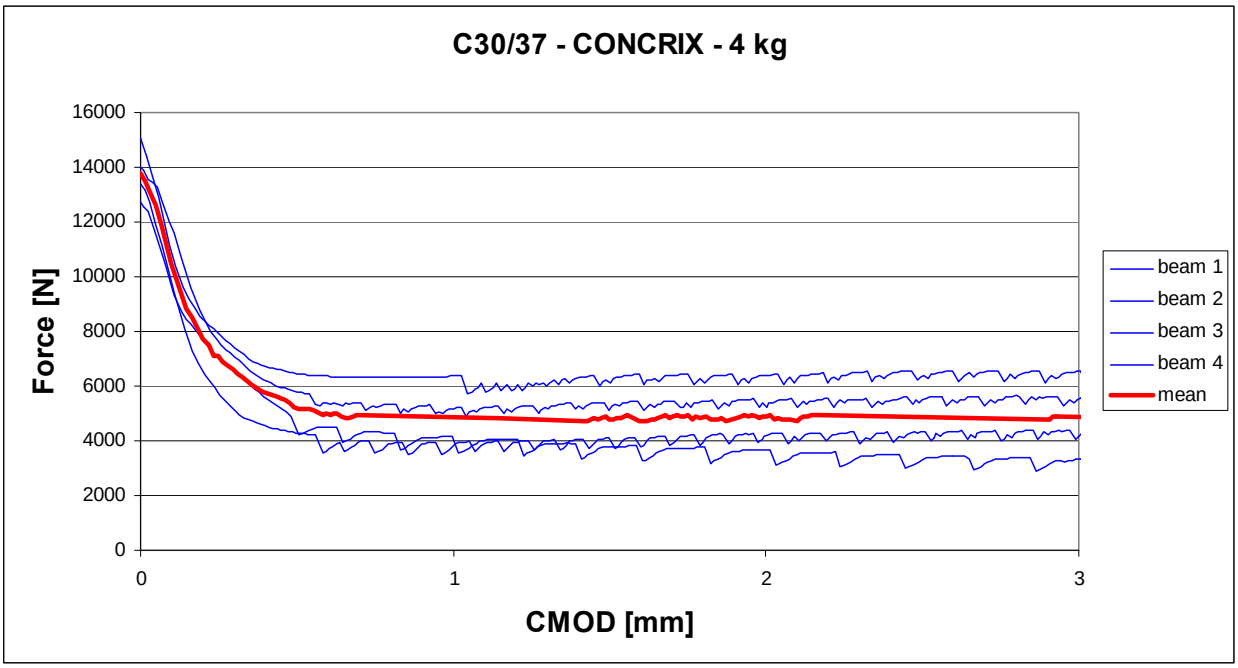
type:	embossed surface polypropylene fibre	
section:	oval	
length:	49 mm	
diameter:	0,7 x 0,35 mm	
weight:	1,01 gram / 100 db	
number in 1 kg:	99010	
dosage:	4 kg/m^3	6 kg/m^3
volume%:	0,4754 m^3/m^3	0,7131 m^3/m^3

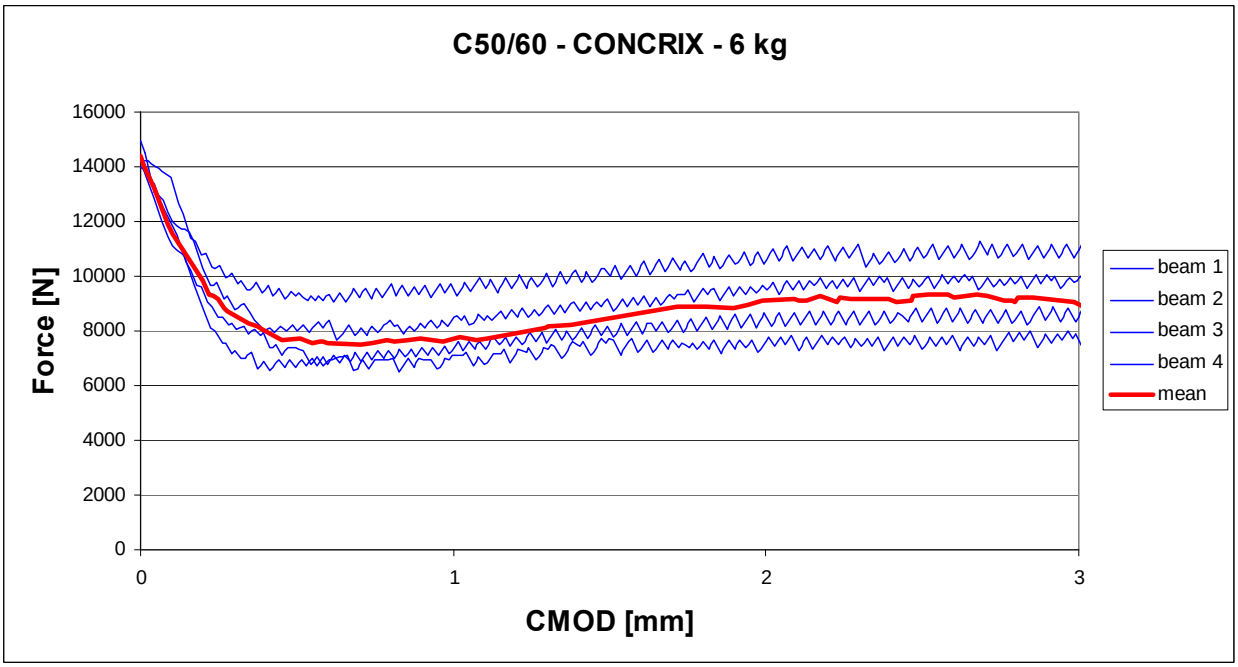
Notes

The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.



Load-CMOD diagrams





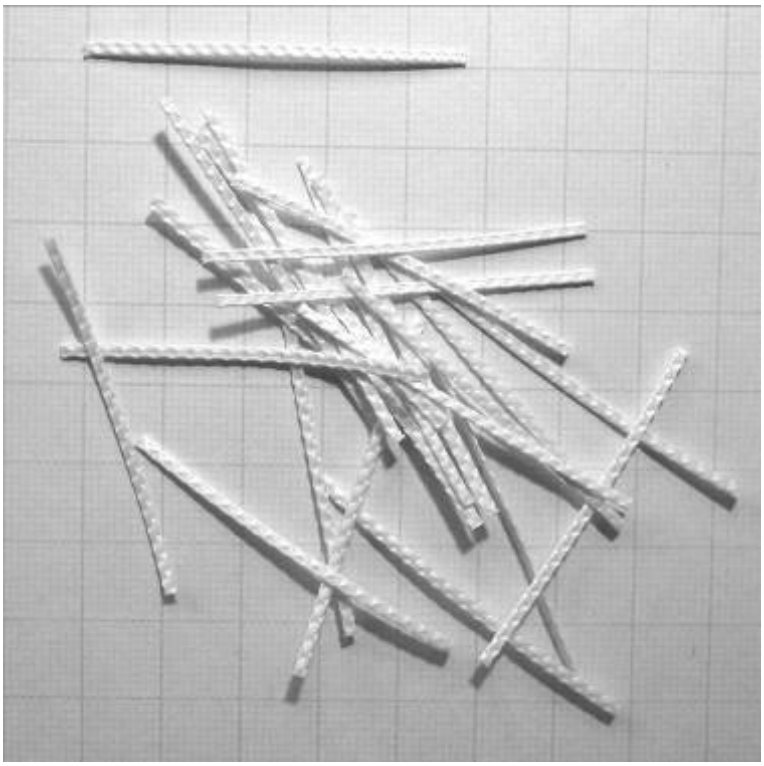
4.5. MAKRO5 – SIKA – dosage 4 kg and 6 kg

Details of the fibre

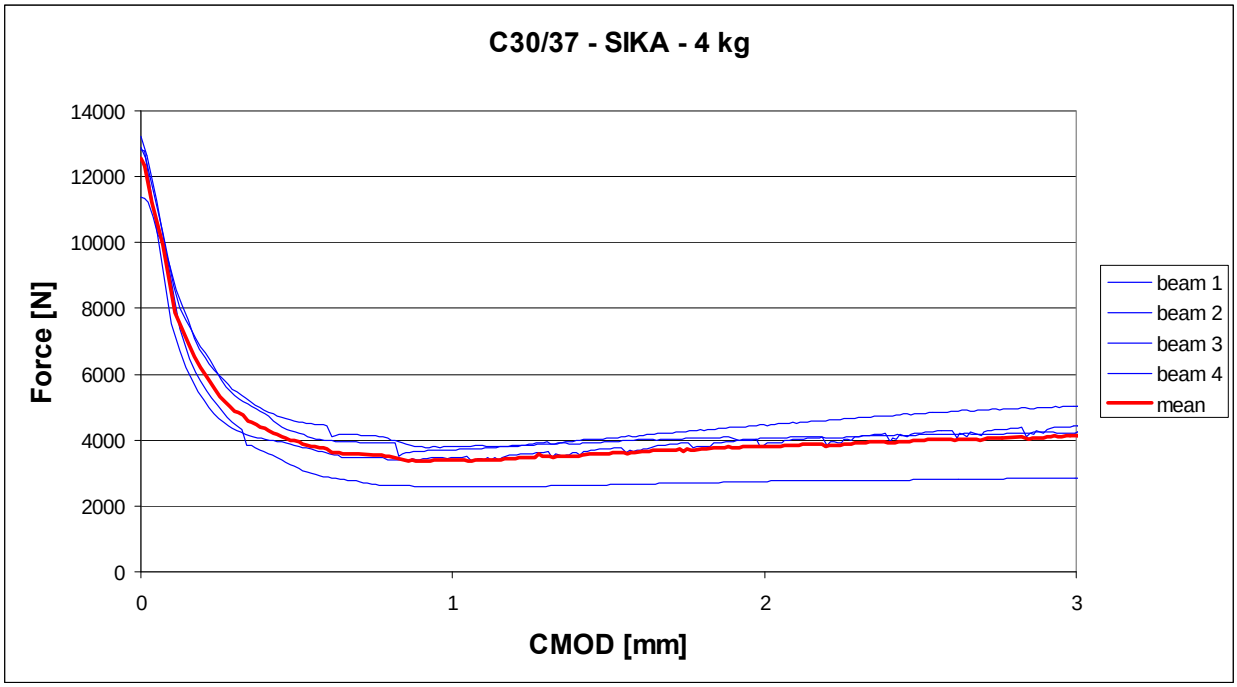
type:	embossed surface polypropylene fibre	
section:	oval	
length:	48 mm	
diameter:	0,65 x 1.55 mm	
weight:	3.32 gram / 100 db	
number in 1 kg:	30120	
dosage:	4 kg/m^3	6 kg/m^3
volume%:	0.5826 m^3/m^3	0.8739 m^3/m^3

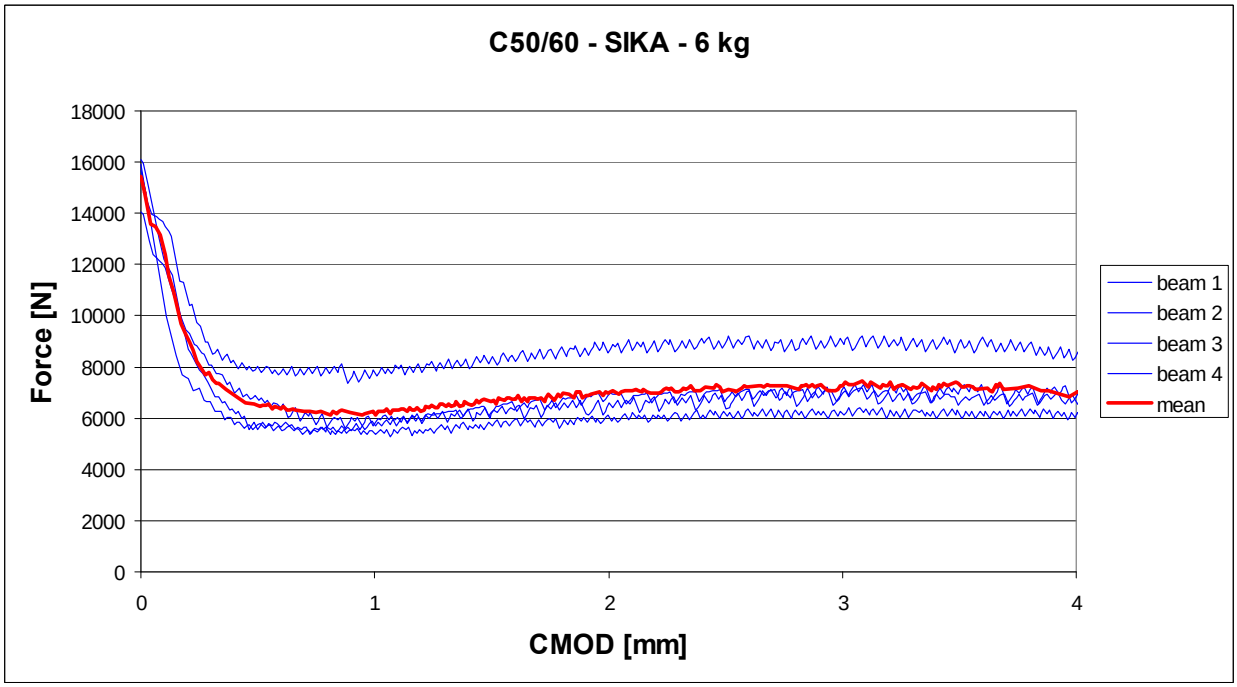
Notes

The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.



Load-CMOD diagrams





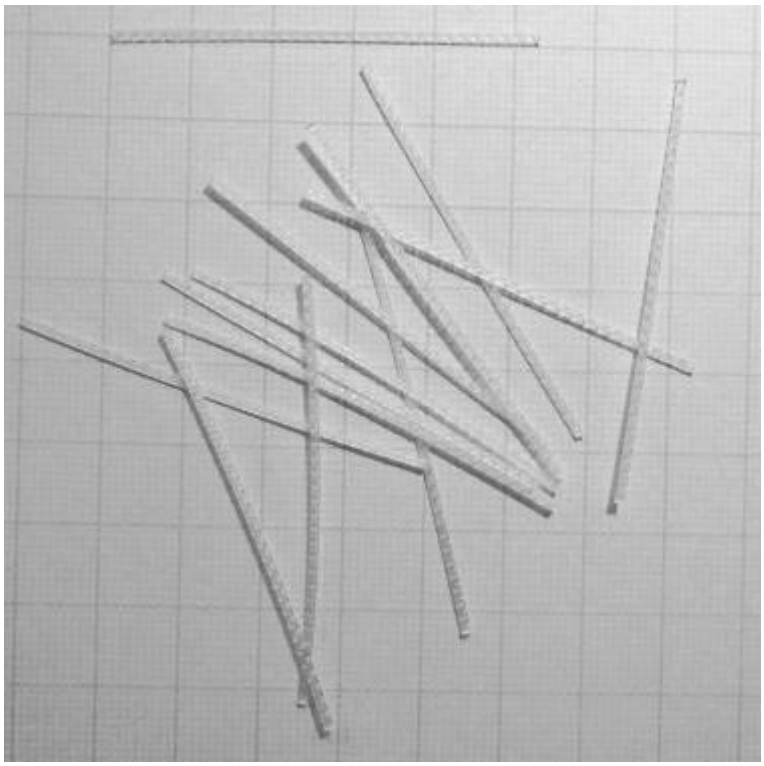
4.6. MAKRO6 – ADFIL – dosage 4 kg and 6 kg

Details of the fibre

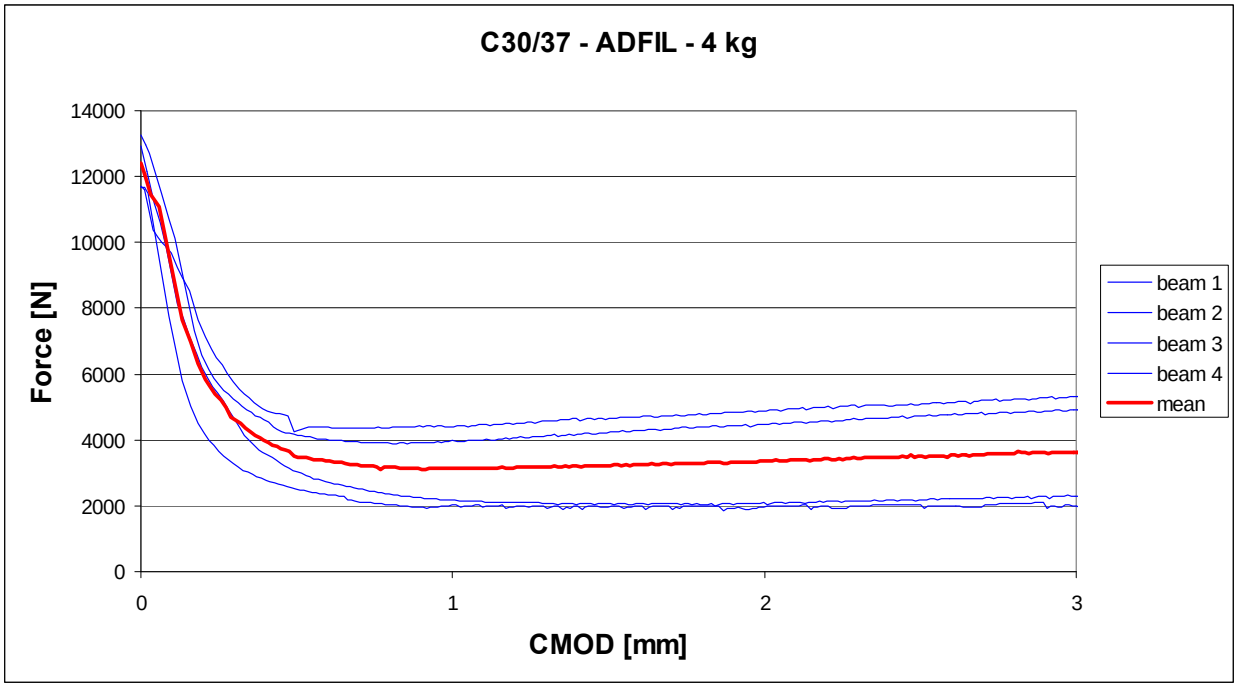
type:	embossed surface polypropylene fibre	
section:	oval	
length:	53 mm	
diameter:	0.7 x 1.10 mm	
weight:	3.27 gram / 100 db	
number in 1 kg:	30581	
dosage:	4 kg/m^3	6 kg/m^3
volume%:	0.4992 m^3/m^3	0.7488 m^3/m^3

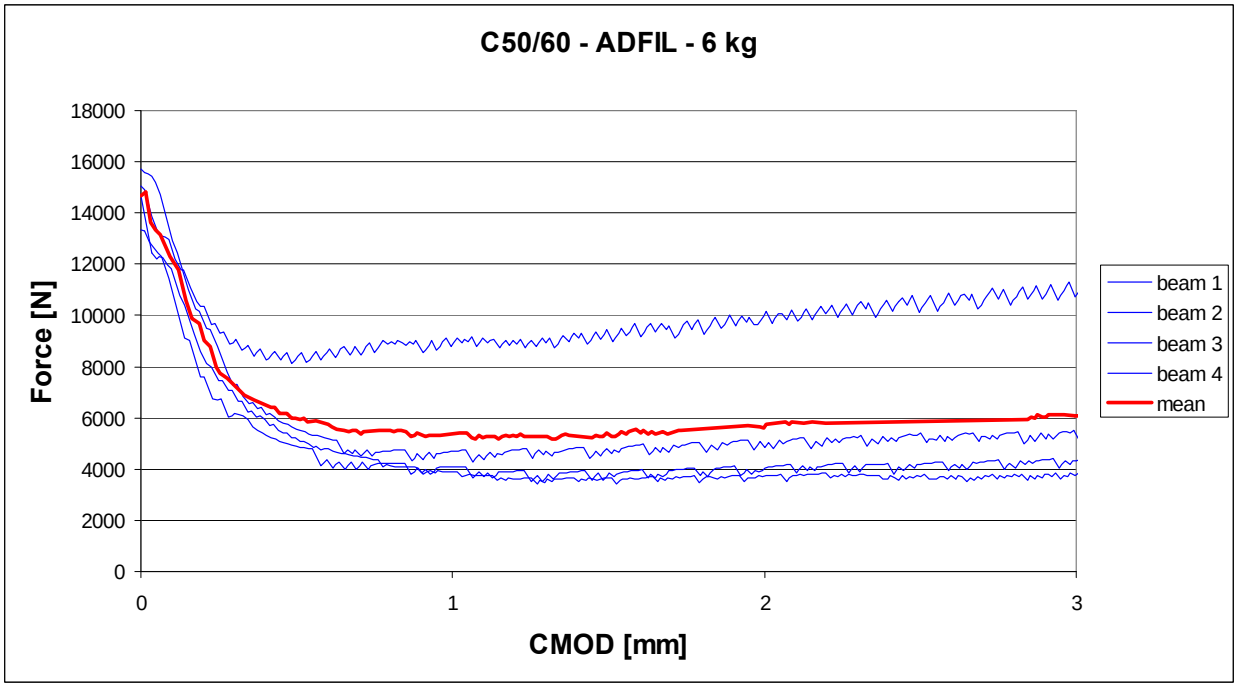
Notes

The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.



Load-CMOD diagrams





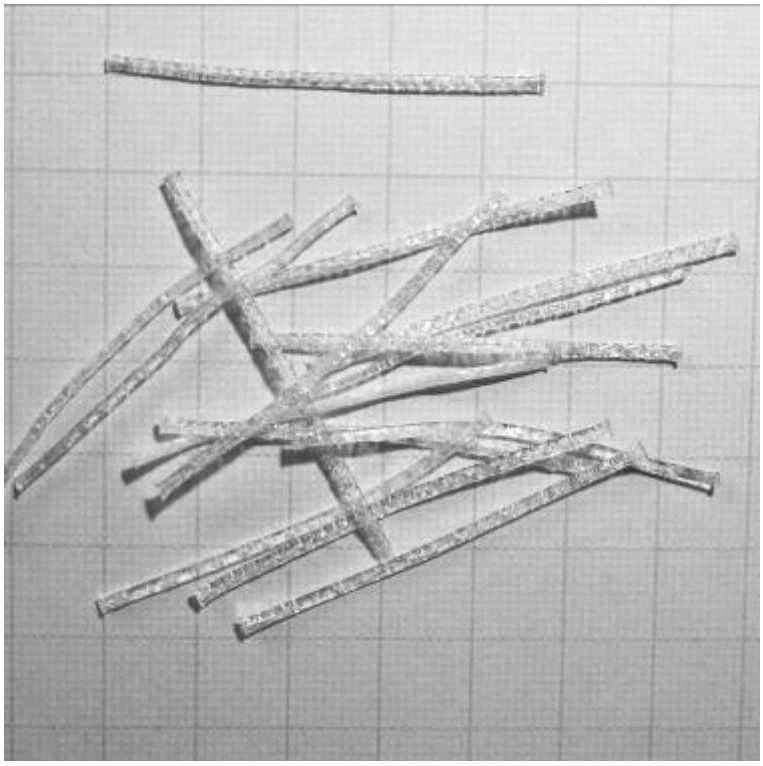
4.7. MAKRO7 – CHRYSO FIBRE GUNITA 50 – dosage 4 kg and 6 kg

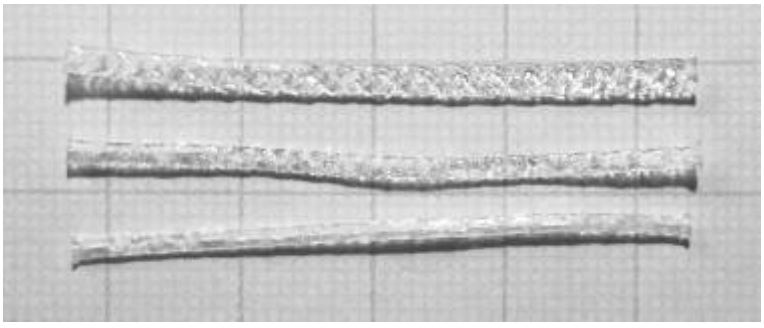
Details of the fibre

type:	embossed surface polypropylene fibre	
section:	oval	
length:	48 mm	
diameter:	0.7 x 1.45 mm	
weight:	4.58 gram / 100 db	
number in 1 kg:	21834	
dosage:	4 kg/m^3	6 kg/m^3
volume%:	0.4255 m^3/m^3	0.6382 m^3/m^3

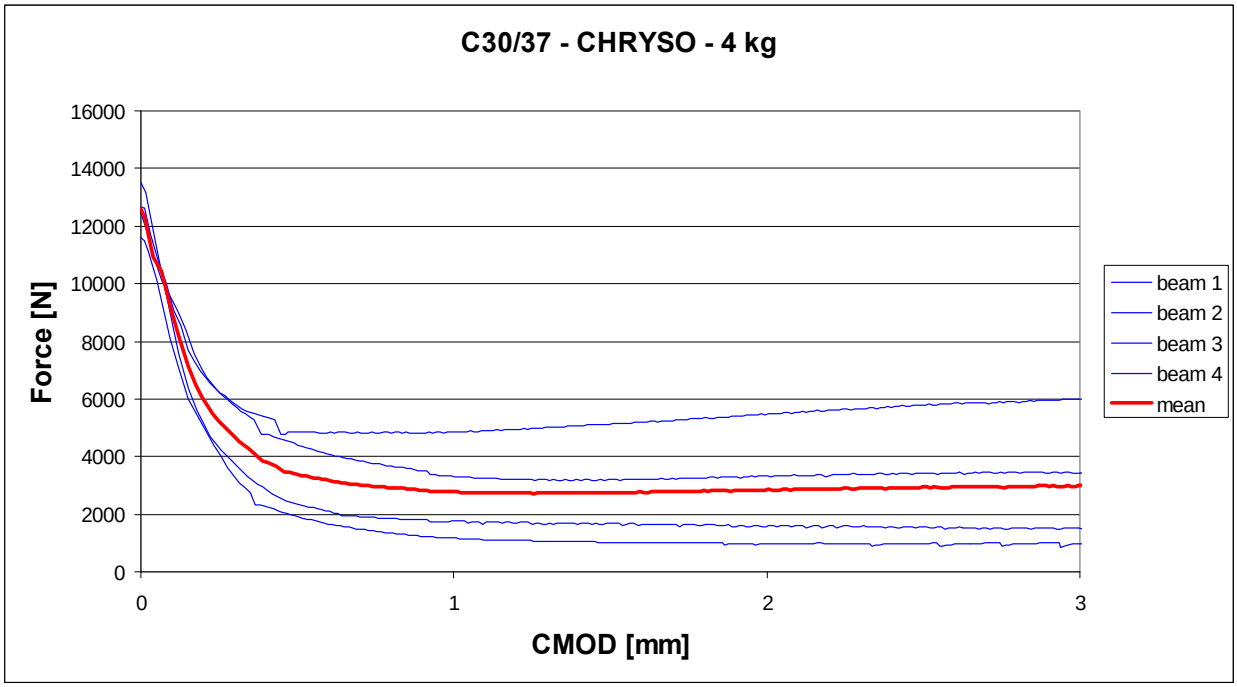
Notes

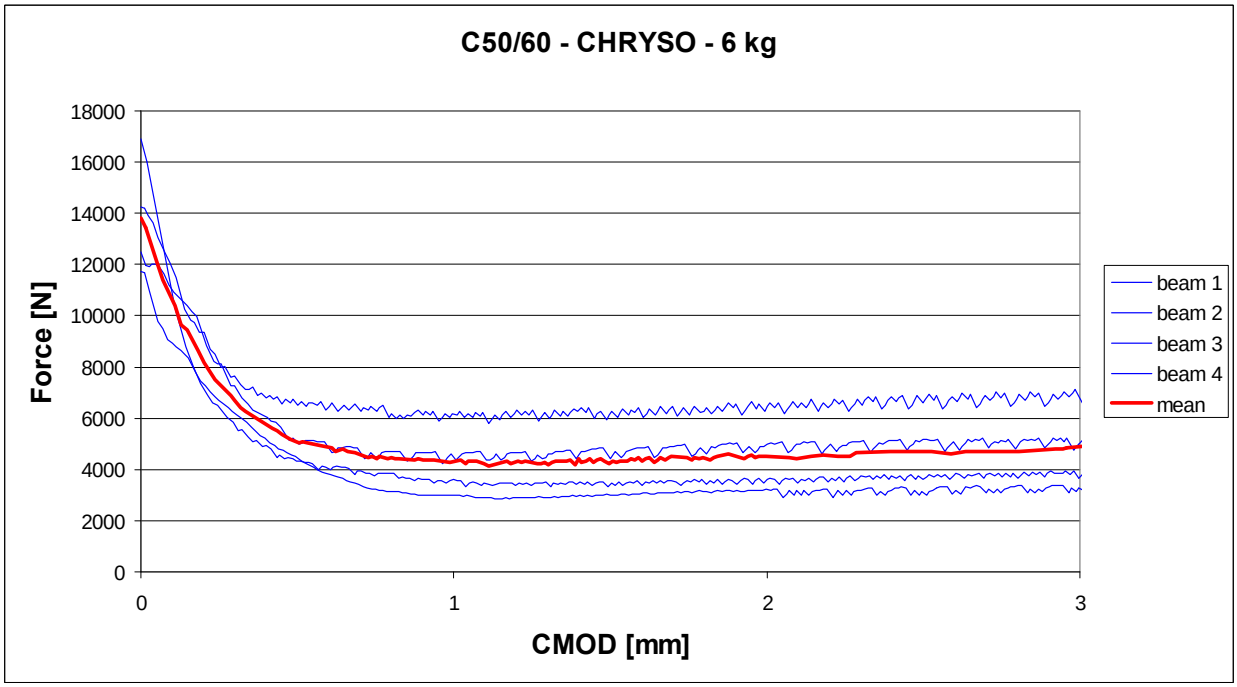
The fibre of the dosage above mixed well, the fresh fibre reinforced concrete was homogenous and easy to compressed.
Major differences could be seen between the individual fibres.



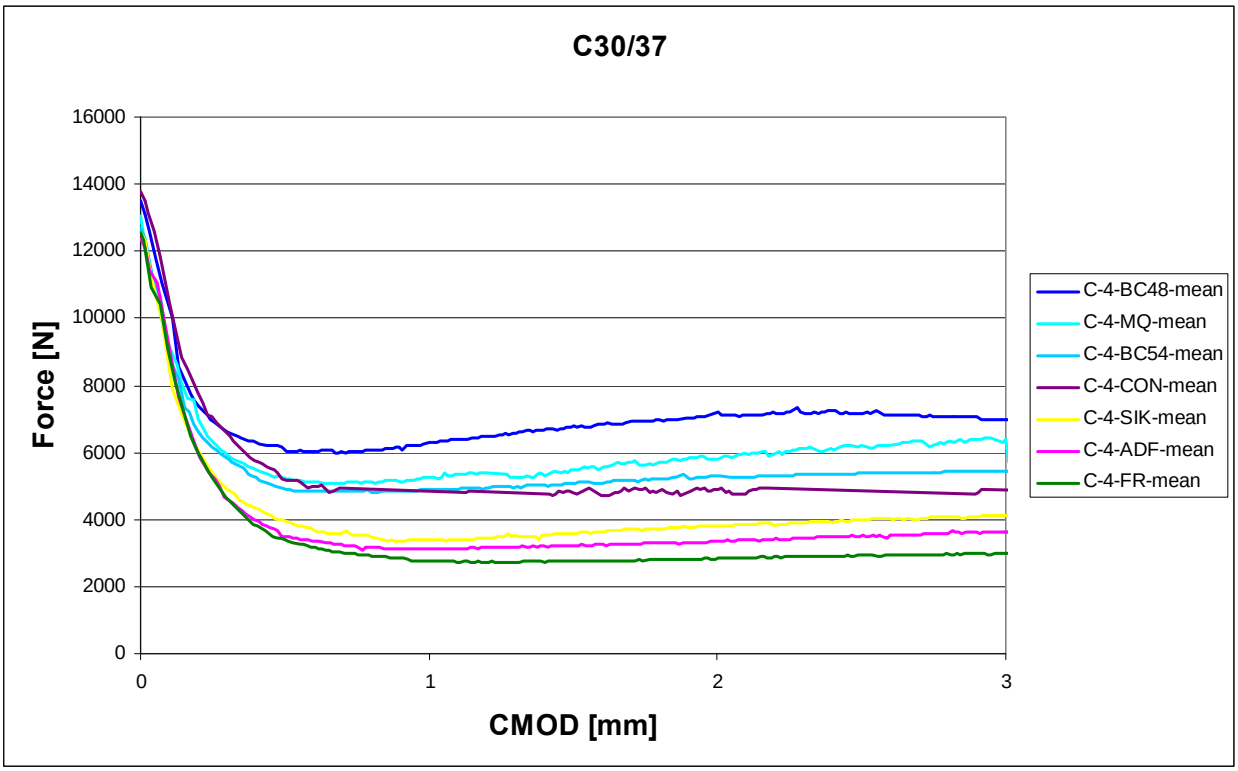


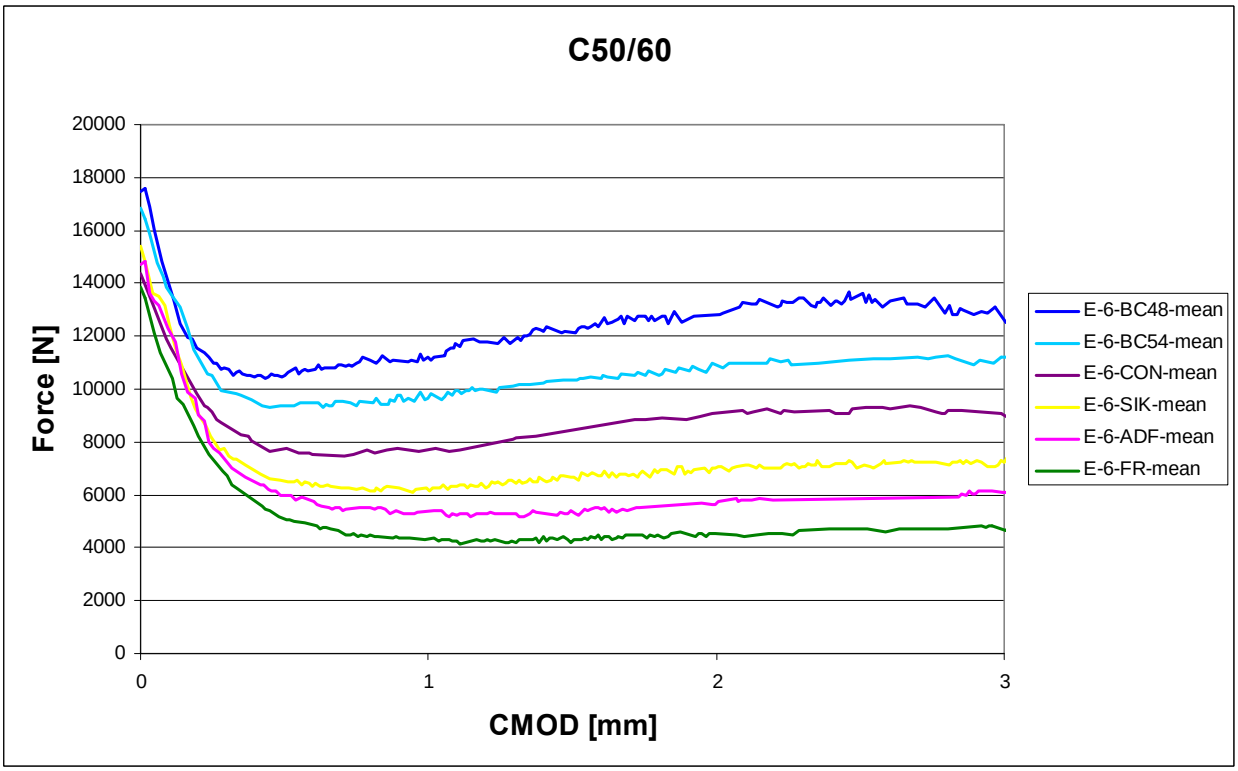
Load-CMOD diagrams

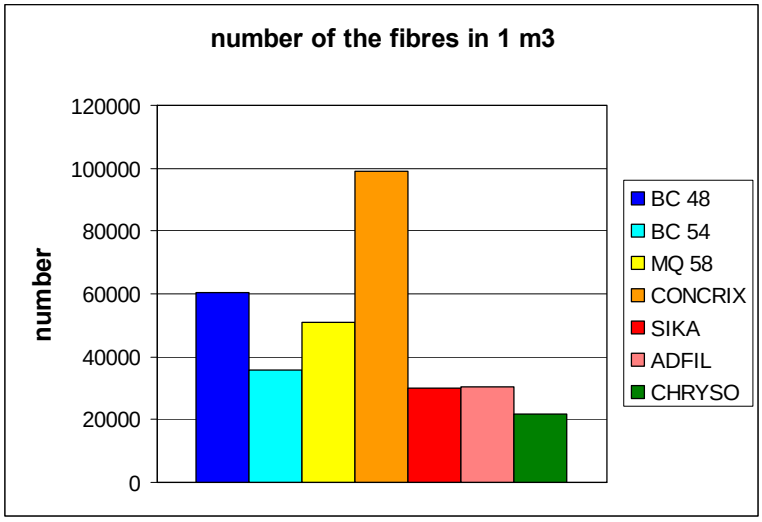


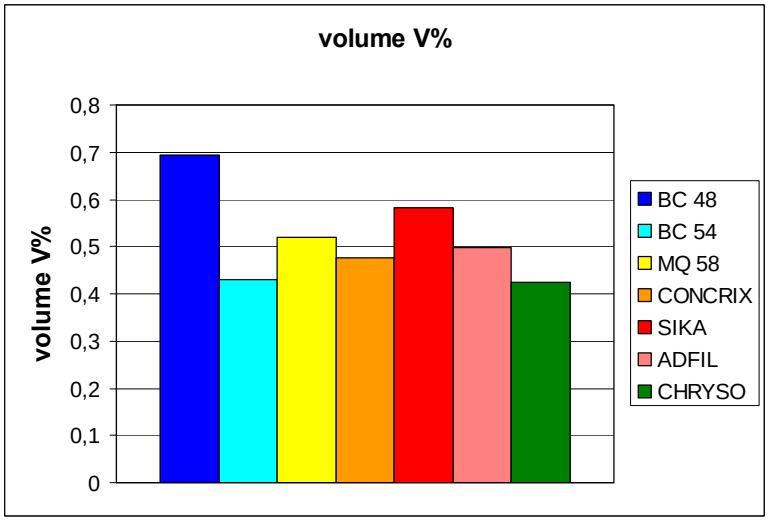


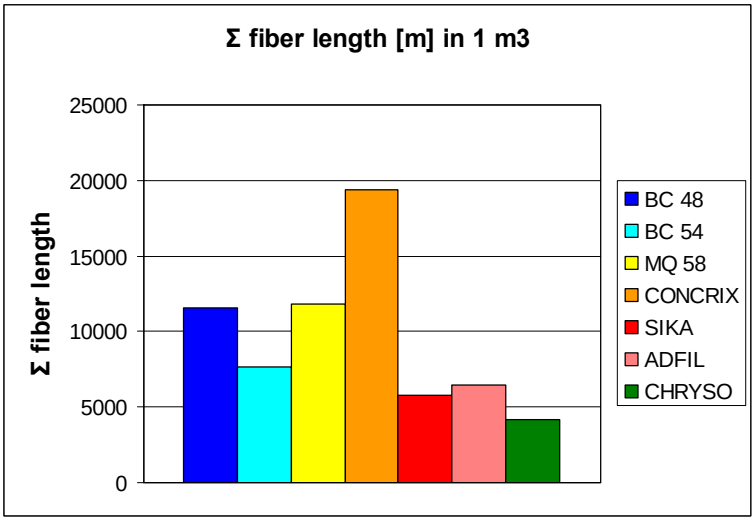
5. Summarized results

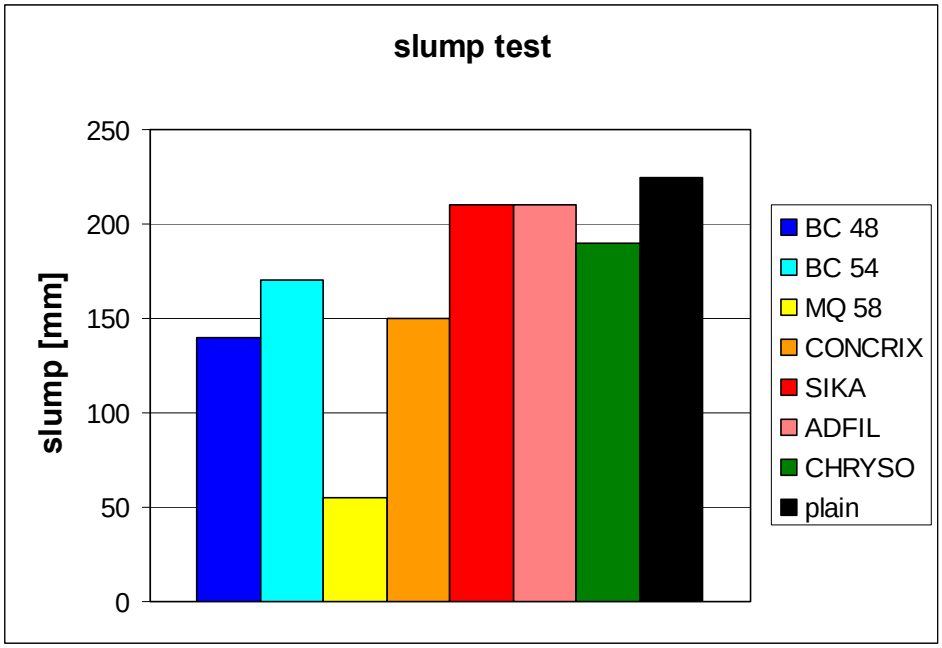


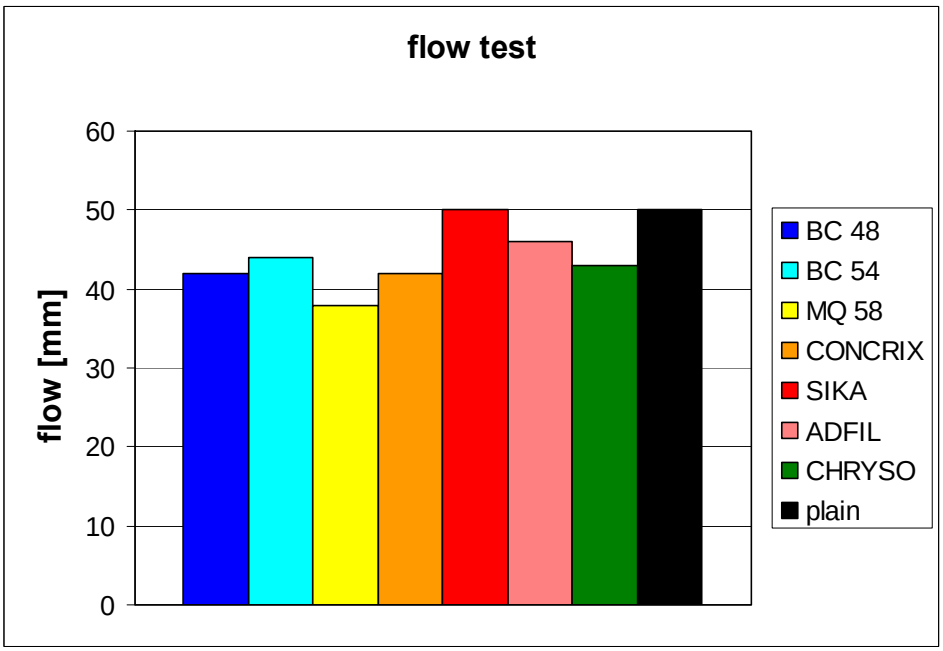



number of the fibres in 1 m3
number
120000
100000
80000
60000
40000
20000
0
BC 48
BC 54
MQ 58
CONCRIX
SIKA
ADFIL
CHRYSO


volume V%
volume V%
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
BC 48
BC 54
MQ 58
CONCRIX
SIKA
ADFIL
CHRYSO


Σ fiber length [m] in 1 m3
Σ fiber length
25000
20000
15000
10000
5000
0
BC 48
BC 54
MQ 58
CONCRIX
SIKA
ADFIL
CHRYSO


slump test
slump [mm]
250
200
150
100
50
0
BC 48
BC 54
MQ 58
CONCRIX
SIKA
ADFIL
CHRYSO
plain


flow test
flow [mm]
60
50
40
30
20
10
0
BC 48
BC 54
MQ 58
CONCRIX
SIKA
ADFIL
CHRYSO
plain

6. Compression test results

sample	cube test		f.cube.test / (f.cube - 4) > 1
	max. force [kN]	stress [MPa]	
A1	1431.20	63.61	1.93
A2	1369.30	60.85	1.84
A3	1201.50	53.39	1.62
A4	1126.80	50.05	1.52
	1282.20	**56.98**	mean
		6.32	dispersion
		2.16	min dispersion
		6.32	sig dispersion
		2.35	Student factor
		42.10	f.ck.cube.test
		37	f.ck.cube C30/37

sample	cube test		f.cube.test / (f.cube - 4) > 1
	max. force [kN]	stress [MPa]	
E1	1764.1	78.41	1.40
E2	1674.6	74.43	1.33
E3	1608.7	71.49	1.28
E4	1568.3	69.7	1.24
	1653.93	**73.51**	mean
		3.81	dispersion
		2.16	min dispersion
		3.81	sig dispersion
		2.35	Student factor
		64.55	f.ck.cube.test
		60	f.ck.cube C50/60

Both of the concrete was in the appropriate strength class!

Annex A - Mix designs

FVM-v130114 Nr / Minta azon			FVM-130204-00				C		Liter	Víztar-
BME - MAPEI szálvizsgálat 2.			Dmax 24						10	talom
C30/37-F3			%	kg/m³	g/cm³	Ft/kg	Liter	Ft	g	%
		CEM 525			3,15	0,000	0			
		CEM I 42,5 R HOLCIM Rohoznik	100,0	**350**	3,10	0,000	113	0	3 500	
		CEM 325			3,10	0,000	0			
		k__w/c__v/(c+k*p)__w/c+PZ500	0,4	0,480	0,480	0,480			Σ CEM	350
		víz		**168**	1,00	0,000	168		965	715
		Pernye			2,10	0,000	0			
		Mikroszilika			1,00	0,000	0			
		MészkőLiszt			2,70	0,000	0			
		BazaltLiszt			1,00	0,000	0			
		OH 0-4 LB York	46	**855**	2,64	0,000	324	0	9 123	6,70
		OK 4-8 LB York	14	**260**	2,64	0,000	99	0	2 652	1,90
		OK 8-16 LB York	20	**372**	2,64	0,000	141	0	3 770	1,40
		OK 16-24 LB York	20	**372**	2,64	0,000	141	0	3 759	1,10
		ZH 0-4 LB York			2,64	0,000	0			
		ZK 4-11 LB York			2,64	0,000	0			
		ZK 11-22 LB York			2,64	0,000	0			
					2,64	0,000	0			
kg	%	Terv . Légtart.	1,5				15,0		19 303	1
0	**0,0**	Össz Adalék.	100	1 859		1m³=	1 000		1	v / c
váz rekonstrukció		Terv. Testsűr.		2 377	v / c				2	f / c
		Dynamon SR 3	0,700	**2,45**	1,07	0,0	2,3	0	24,50	22,90
		0								
		0								
		0								

Mix design of the concrete C

FVM-v130114 Nr / Minta azon				C50 Dmax 22 NZ			E OH Busped b		m3 8	Víztar-talom
BME - MAPEI szálvizsgálat 2.										
C30/37-F3				%	kg/m³	g/cm³	Ft/kg	Liter	Ft	Kg	%
			CEM 525			3,15	0,000	0			
			CEM I 42,5 R HOLCIM Rohoznik	100,0	**465**	3,10	0,000	150	0	3 720	
			CEM 325			3,10	0,000	0			
			k__w/c__v/(c+k*p)__w/c+PZ500	0,4	0,387	0,387	0,387			Σ CEM	465
			víz		**180**	1,00	0,000	180		1 105	335
			Pernye			2,10	0,000	0			
			Mikroszilika			1,00	0,000	0			
			MészkőLiszt			2,70	0,000	0			
			BazaltLiszt			1,00	0,000	0			
		OH 0-4	LB York	38	**657**	2,64	0,000	249	0	5 502	4,67
		OK 4-8	LB York			2,64	0,000	0			
		OK 8-16	LB York			2,64	0,000	0			
		OK 16-24	LB York			2,64	0,000	0			
		ZH 0-4	LB York			2,64	0,000	0			
		ZK 4-11	LB Yorks	20	**346**	2,64	0,000	131	0	2 806	1,42
		ZK 11-22	LB Yorks	42	**726**	2,64	0,000	275	0	5 861	0,87
						2,64	0,000	0			
kg	%	Terv . Légtart.		1,5				15,0		14 169	1
0	**0,0**	Össz Adalék.		100	1 729		1m³=	1 000		1	v / c
váz rekonstrukció		Terv. Testsűr.			2 374	v / c				2	f / c
		Dynamon SR 3		1,250	**5,81**	1,07	0,0	5,4	0	46,50	43,46
		0									
		0									
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Mix design of the concrete E