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THE INFLUENCE OF SELECTED COMPOSITION FACTORS ON THE RHEOLOGICAL PROPERTIES OF FIBRE REINFORCED FRESH MORTAR

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INTRODUCTION

- The addition of fibres will cause problems with workability to occur,
- In the research, an experimental verification of a significance of an influence: W/C ratio, volume fraction of fibres, lengths and kind of materials of fibres on rheological properties of FRFM was investigated,
- The influence of these factors is still not recognized in sufficient measure,

THE MAIN GOAL OF RESEARCH

- Determination rheological behaviour of fibre reinforced fresh mortar in investigation with rotary rheometer,

- The recognize of real nature workability of the FRFM, investigation of rheological properties of the mortars, their rheological parameters: yield value **g** and plastic viscosity **h**

CHARACTERISTICS OF THE FIBRES

Type of fiber	Longitudinal profile	Cross-section shape	Fiber Length (mm)	Designation
Polypropylene	collated **fibrillated** fiber bundles	Circular in rovings	**6 – 12 - 19**	[H6/H12/H19]
Polypropylene	**monofilament** form	Circular	**3 – 6 - 12**	[F3/F6/F12]
Steel	monofilament fibre, straight	Circular	**6 - 13**	[S6/S13]
Glass	collated fibrillated fiber bundles	Circular	**13**	[G13]
Carbon	monofilament fibre, „pitch” type	Rectangular	**3 – 6 - 10**	[C3/C6/C10]

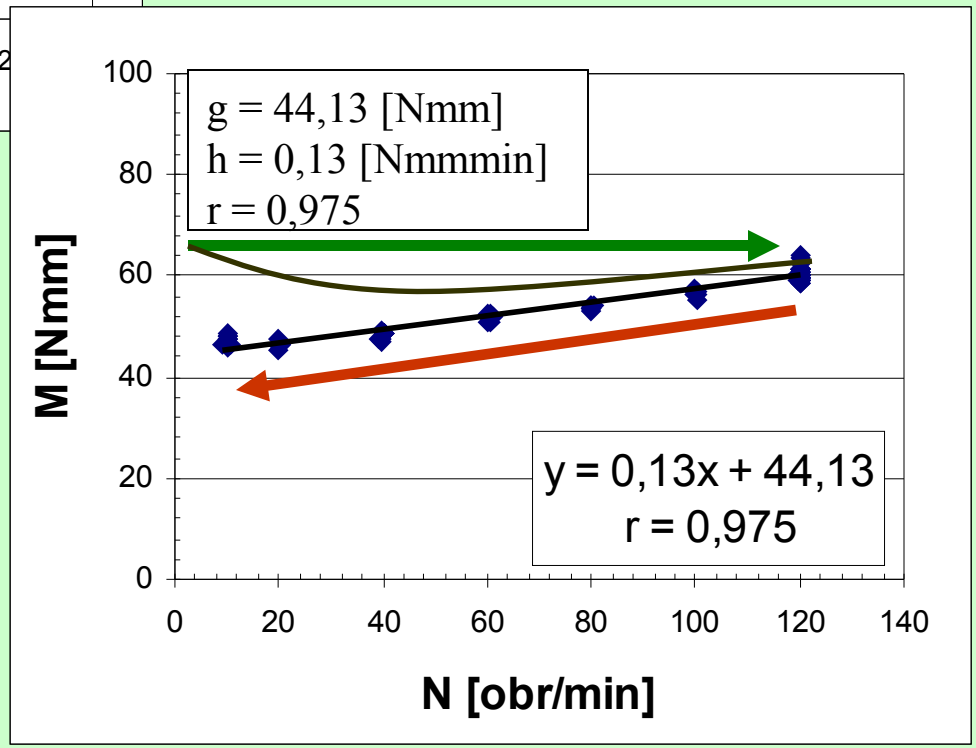
EXPERIMENTAL - 1

- The investigation was carried out on standard mortar according to PN EN 196-1: 1996, because of a similar nature, of mortar and concrete and smaller cost as well as labour consumption at the same time,
- The content of superplasticizer FM 34 was constant and equal to 1% of cement weight,
- Portland cement sulfate resistant, call “road” CEM I MSR 42,5 was used,
- The temperature of mortar was 20±2oC.

EXPERIMENTAL - 2

Stage	Main goal of stage	Variables
I	Influence of W/C ratio (without fibres)	1. W/C ratio – 0.43-0.45–0.47–0.50 2. SP content – 0; 1; 2%
II	Influence of polypropylene fibres (SP = 1%)	1. W/C ratio – 0.45–0.47–0.50–0.53 2. Type of polypropylene fibres – fibrillated 3. Fibre length – 3; 6; 12; 19 mm 4. Fibre volume fraction – 0.1; 0.3; 0.5%
III	Influence of glass fibres (SP = 1%)	1. W/C ratio – 0.45–0.47–0.50–0.53 2. Fibre volume fraction – 0.1; 0.3; 0.5%
IV	Influence of steel fibres (SP = 1%)	1. W/C ratio – 0.45–0.47–0.50–0.53 2. Fibre length – 6; 13 mm 3. Fibre volume fraction – 0.1; 0.3; 0.5%
V	Influence of carbon fibres (SP = 1%)	1. W/C ratio – 0.45–0.47–0.50–0.53 2. Fibre length – 3; 6; 10 mm 3. Fibre volume fraction – 0.1; 0.3; 0.5%

Measuring procedure and the rotary rheometer



Analysis of variance for yield value **g** and plastic viscosity **h** of **polypropylene** FRFM.

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level
ANOVA for:	**Yield value g**					**Plastic viscosity h**				
MAIN EFFECTS										
A: W / C	294.400	5	58.880	1.036	0.404	0.597	5	0.119	11.8	0.000
B: Type of fibres	2855.114	2	1427.56	25.120	0.000	0.020	2	0.010	0.991	0.377
C: Fibre length	628.107	4	157.027	2.763	0.034	0.142	4	0.036	3.514	0.012
D: Fibre volume fraction	1388.200	2	694.100	12.214	0.000	0.020	2	0.010	0.987	0.378
INTERACTIONS										
BD	1541.723	4	378.681	6.663	0.000	0.043	4	0.011	1.072	0.377
Residual	3864.47	68	56.831			0.6879	68	0.010		
Total (corrected)	11236.56	85				1.6347	85			

Analysis of variance for yield value **g** and plastic viscosity **h** of **polypropylene** FRFM.

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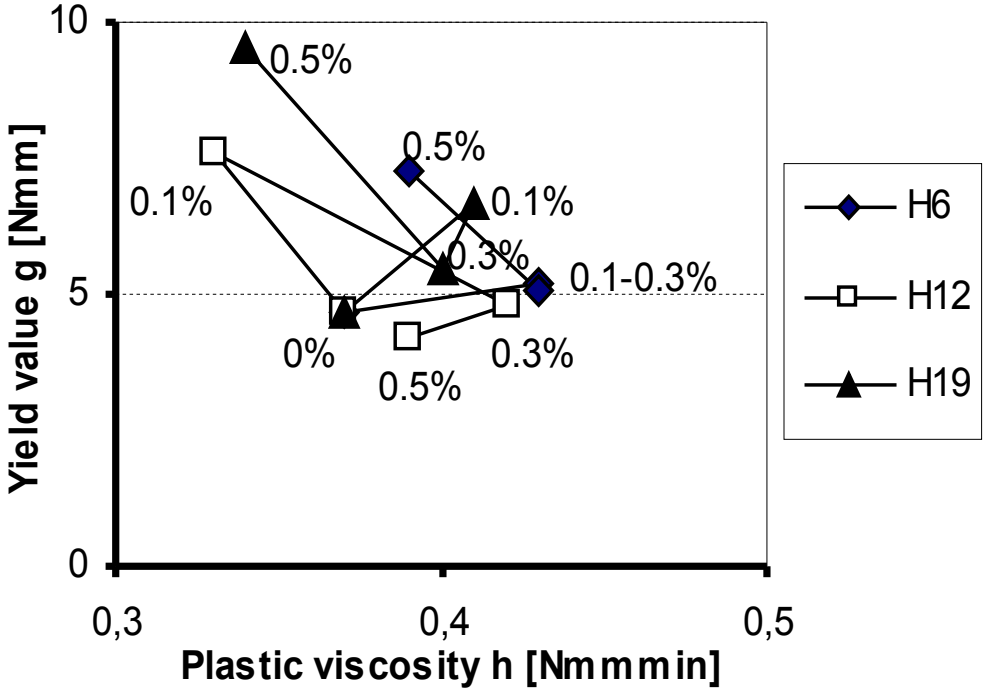
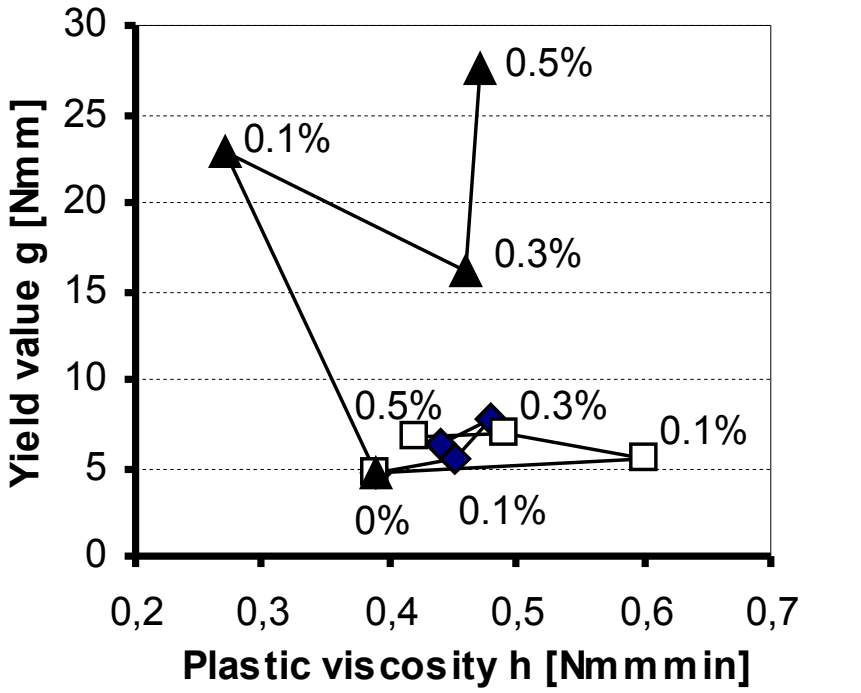
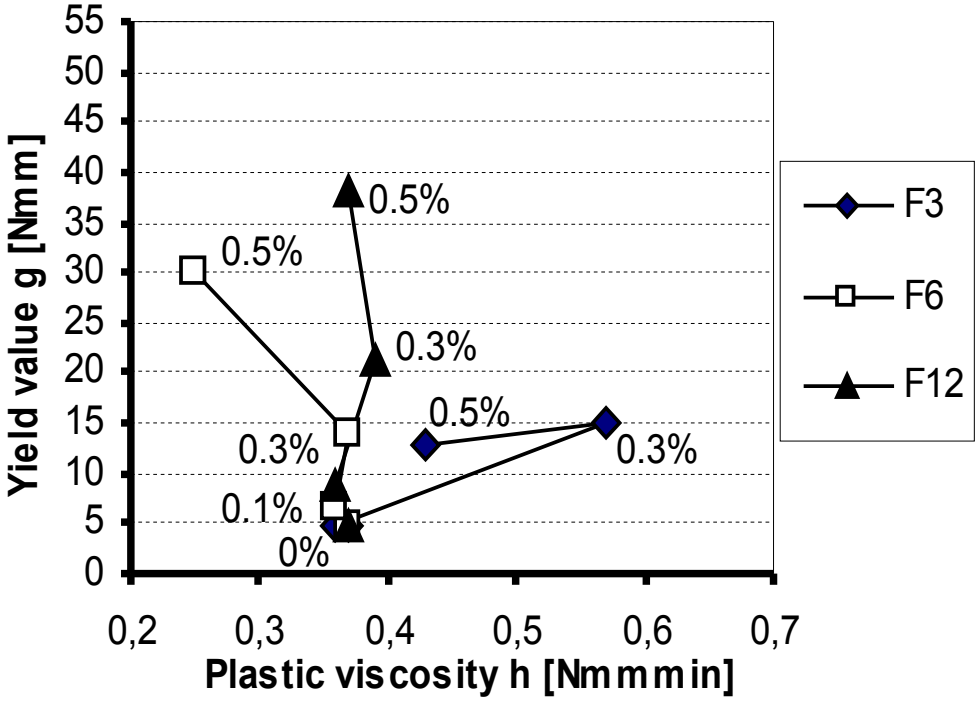
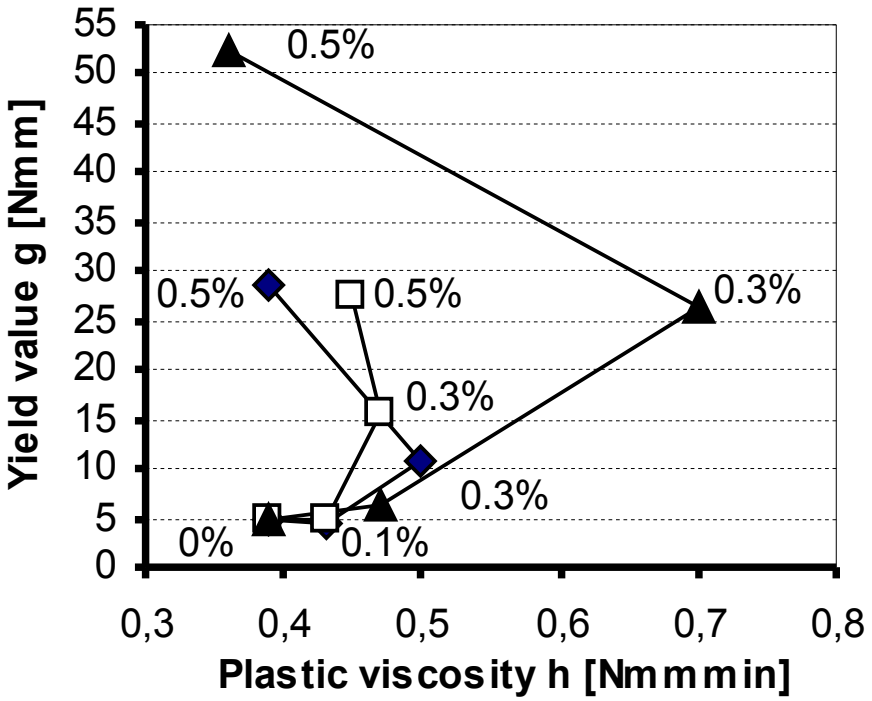
Influence the length and volume fraction of **polypropylene fibrillated fibres** on rheological parameters of FRFM; a) W/C = 0.53; b) W/C = 0.50





Influence the length and volume fraction of **polypropylene monofilament fibres** on rheological parameters of FRFM; a) W/C = 0.53; b) W/C = 0.50





Analysis of variance for yield value **g** and plastic viscosity **h** of **glass** FRFM.

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level
ANOVA for:	**Yield value g**					**Plastic viscosity h**				
MAIN EFFECTS										
A: W / C	221.340	3	73.780	1.175	0.567	0.007	3	0.002	1.925	0.470
B: Fibre volume fraction	321.798	2	160.899	2.562	0.398	0.001	2	0.000	0.262	0.810
Residual	62.806	1	62.806			0.001	1	0.001		
Total (corrected)	452.468	6				0.016	6			

Analysis of variance for yield value **g** and plastic viscosity **h** of **steel** FRFM.

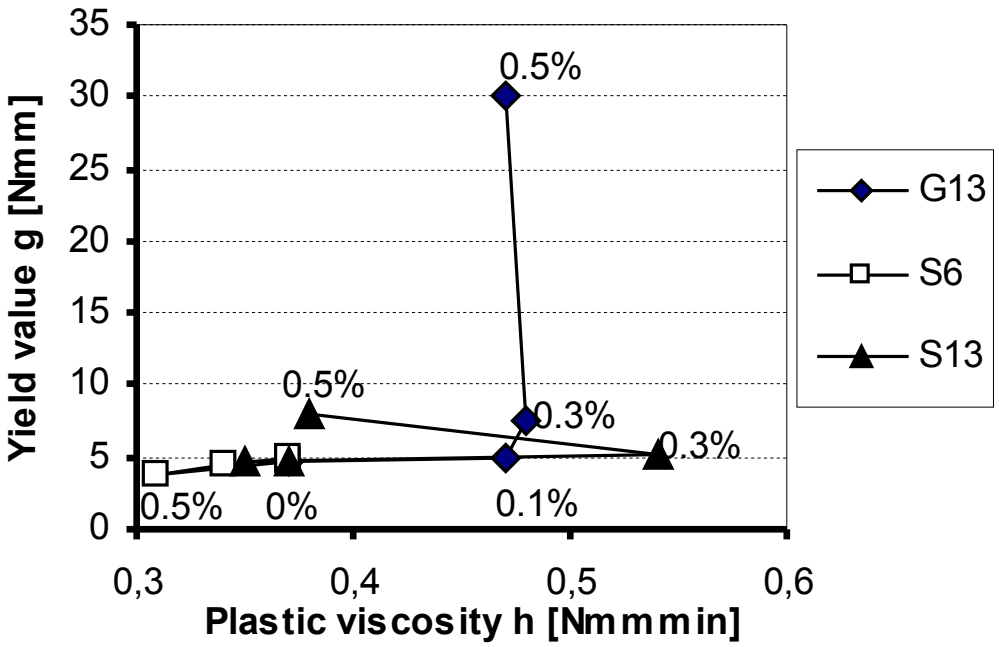
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level
ANOVA for:	**Yield value g**					**Plastic viscosity h**				
MAIN EFFECTS										
A: W / C	196.727	3	65.576	8.132	0.000	0.516	3	0.172	110.31	0.000
B: Fibre length	47.649	1	47.649	5.909	0.020	0.107	1	0.107	68.578	0.000
C: Fibre volume fraction	46.888	2	23.444	2.907	0.067	0.088	2	0.044	28.154	0.000
D:Measurement repetition	9.590	2	4.795	0.595	0.557	0.000	2	0.000	0.231	0.795
INTERACTIONS										
AB	23.106	3	7.702	0.955	0.424	0.003	3	0.001	0.708	0.553
AD	47.114	6	7.852	0.974	0.456	0.006	6	0.001	0.688	0.661
BC	57.561	2	28.781	3.569	0.038	0.021	2	0.011	6.811	0.003
BD	7.104	2	3.552	0.44	0.647	0.000	2	0.000	0.212	0.810
CD	26.074	4	6.518	0.808	0.528	0.000	4	0.000	0.061	0.993
Residual	314.5096	39	8.064			0.0608	39	0.001		
Total (corrected)	741.29	64				0.8127	64			

Analysis of variance for yield value **g** and plastic viscosity **h** of **steel** FRFM.

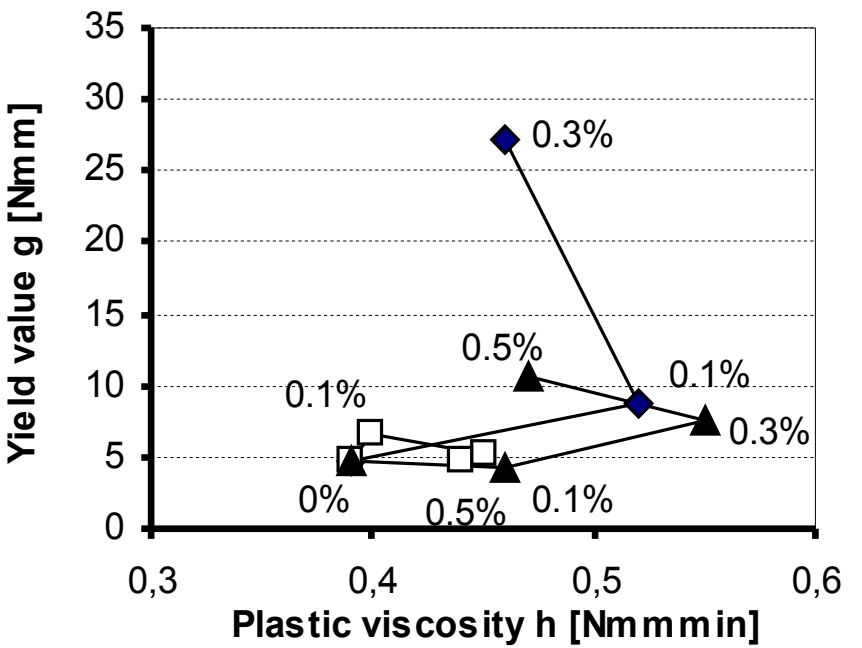
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level
ANOVA for:	**Yield value g**					**Plastic viscosity h**				
MAIN EFFECTS										
A: W / C	196.727	3	65.576	8.132	**0.000**	0.516	3	0.172	110.31	**0.000**
B: Fibre length	47.649	1	47.649	5.909	0.020	0.107	1	0.107	68.578	**0.000**
C: Fibre volume fraction	46.888	2	23.444	2.907	0.067	0.088	2	0.044	28.154	**0.000**
D:Measurement repetition	9.590	2	4.795	0.595	0.557	0.000	2	0.000	0.231	0.795
INTERACTIONS										
AB	23.106	3	7.702	0.955	0.424	0.003	3	0.001	0.708	0.553
AD	47.114	6	7.852	0.974	0.456	0.006	6	0.001	0.688	0.661
BC	57.561	2	28.781	3.569	0.038	0.021	2	0.011	6.811	0.003
BD	7.104	2	3.552	0.44	0.647	0.000	2	0.000	0.212	0.810
CD	26.074	4	6.518	0.808	0.528	0.000	4	0.000	0.061	0.993
Residual	314.5096	39	8.064			0.0608	39	0.001		
Total (corrected)	741.29	64				0.8127	64			

Influence the length and volume fraction of **glass and steel fibres** on rheological parameters of FRFM;

a) W/C = 0.53;



b) W/C = 0.50



Analysis of variance for yield value **g** and plastic viscosity **h** of **carbon** FRFM.

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level
ANOVA for:	**Yield value g**					**Plastic viscosity h**				
MAIN EFFECTS										
A: W / C	588.376	3	196.125	2.425	0.078	0.161	3	0.054	8.551	0.000
B: Fibre length	892.934	3	297.645	3.680	0.019	0.101	3	0.034	5.349	0.003
C: Fibre volume fraction	12460.93	2	6230.47	77.041	0.000	0.238	2	0.119	18.998	0.000
D:Measurement repetition	120.005	2	60.003	0.742	0.482	0.017	2	0.008	1.343	0.271
INTERACTIONS										
AB	213.676	9	23.742	0.294	0.973	0.039	9	0.004	0.696	0.709
AD	330.615	6	55.102	0.681	0.665	0.035	6	0.006	0.931	0.483
BD	112.882	6	18.813	0.233	0.964	0.008	6	0.001	0.208	0.973
Residual	3639.225	45	80.8716			0.2823	45	0.00627		
Total (corrected)	20991.04	76				1.2259	76			

Analysis of variance for yield value **g** and plastic viscosity **h** of **carbon** FRFM.

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level	Sum of Squares	d.f.	Mean square	F-ratio	Sig. Level
ANOVA for:	**Yield value g**					**Plastic viscosity h**				
MAIN EFFECTS										
A: W / C	588.376	3	196.125	2.425	0.078	0.161	3	0.054	8.551	**0.000**
B: Fibre length	892.934	3	297.645	3.680	0.019	0.101	3	0.034	5.349	**0.003**
C: Fibre volume fraction	12460.93	2	6230.47	77.041	**0.000**	0.238	2	0.119	18.998	**0.000**
D:Measurement repetition	120.005	2	60.003	0.742	0.482	0.017	2	0.008	1.343	0.271
INTERACTIONS										
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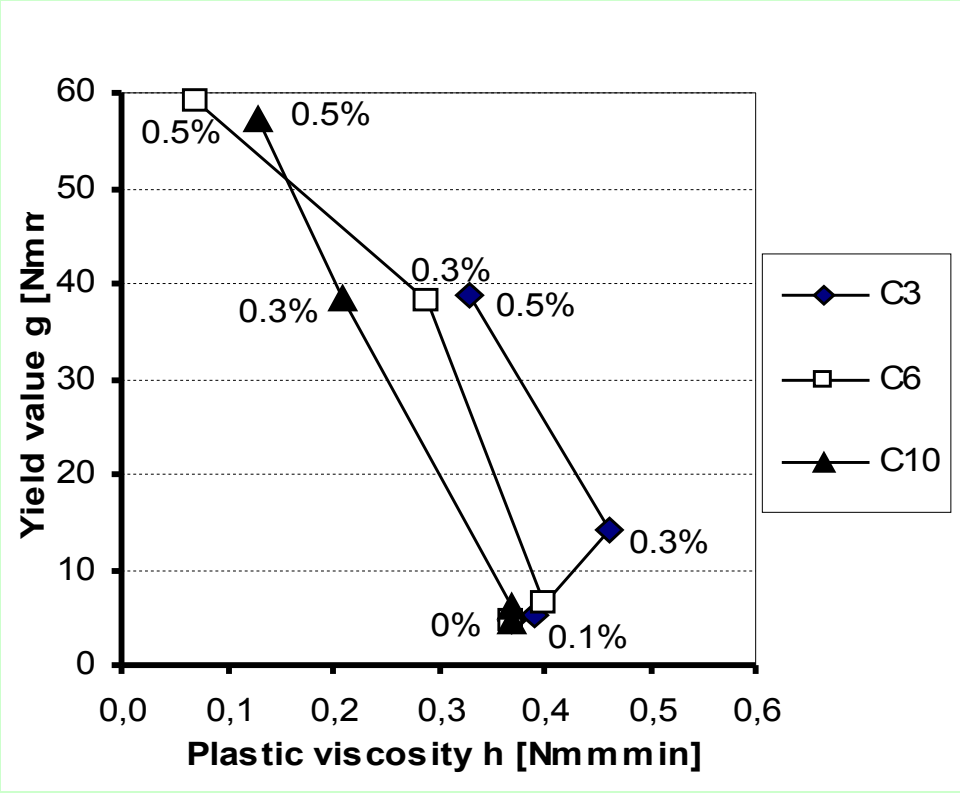
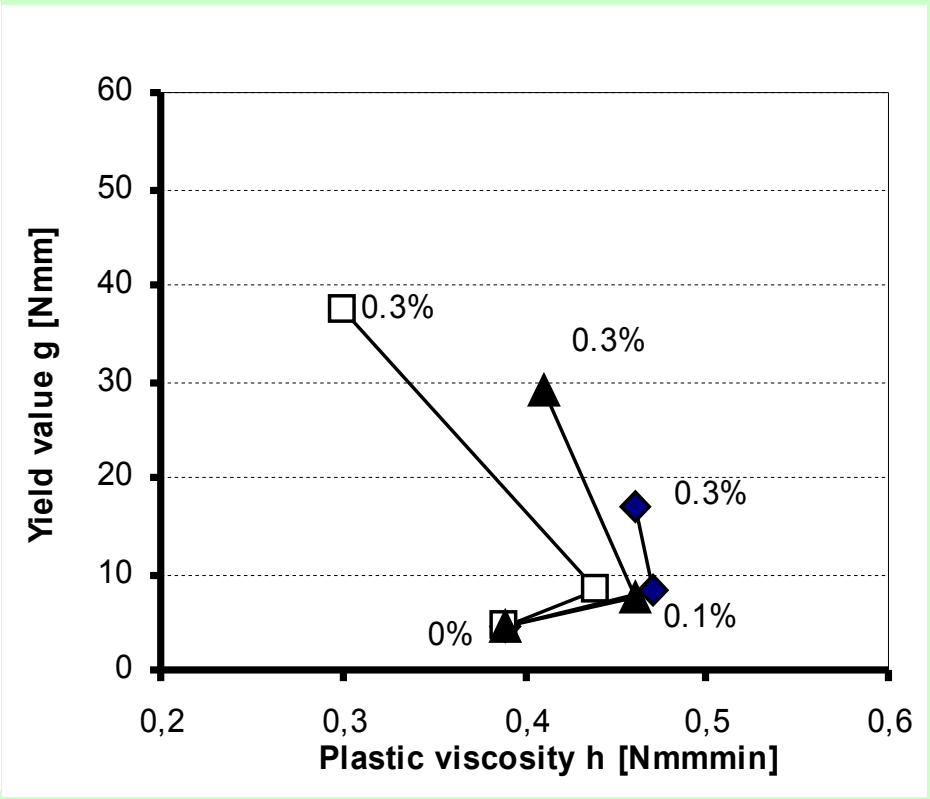
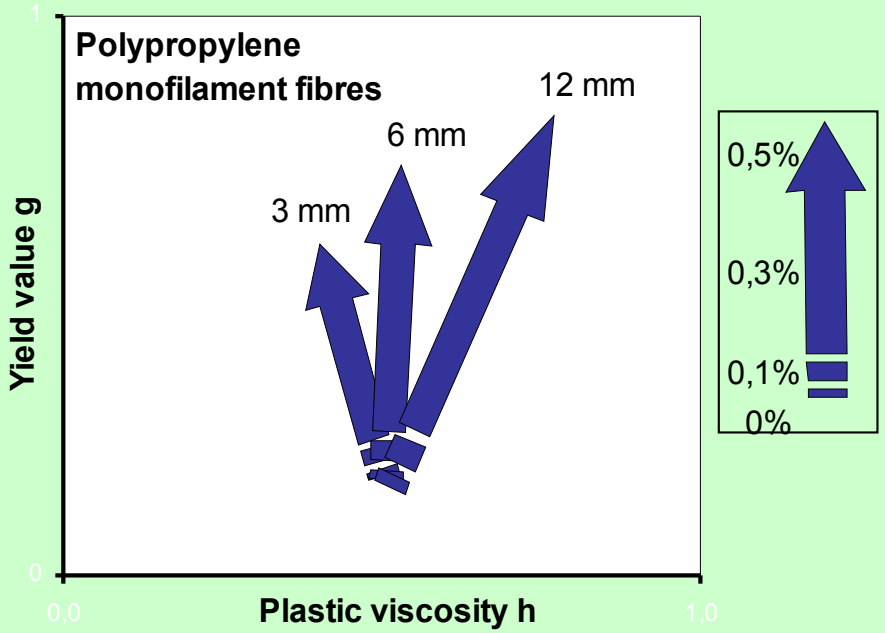
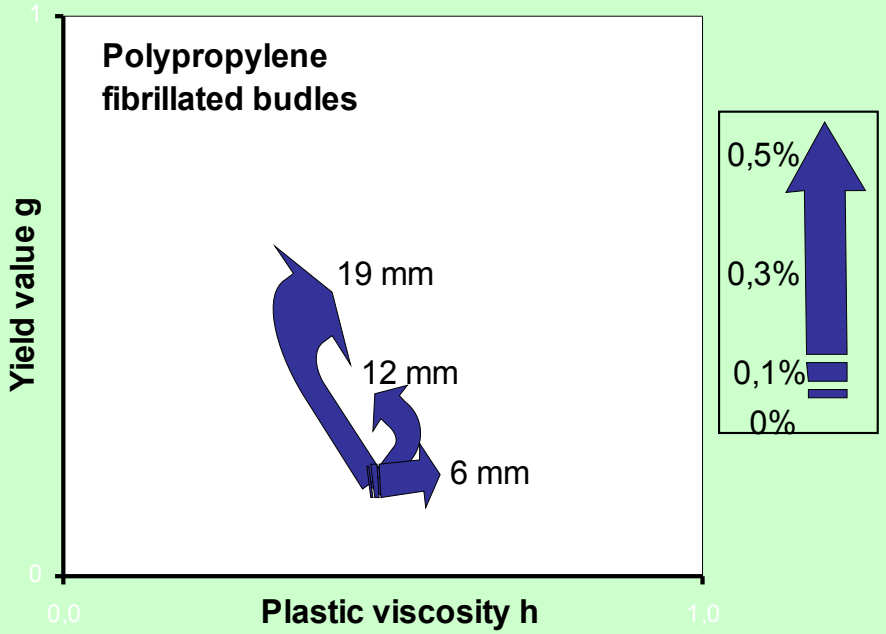
AD	330.615	6	55.102	0.681	0.665	0.035	6	0.006	0.931	0.483
BD	112.882	6	18.813	0.233	0.964	0.008	6	0.001	0.208	0.973
Residual	3639.225	45	80.8716			0.2823	45	0.00627		
Total (corrected)	20991.04	76				1.2259	76			

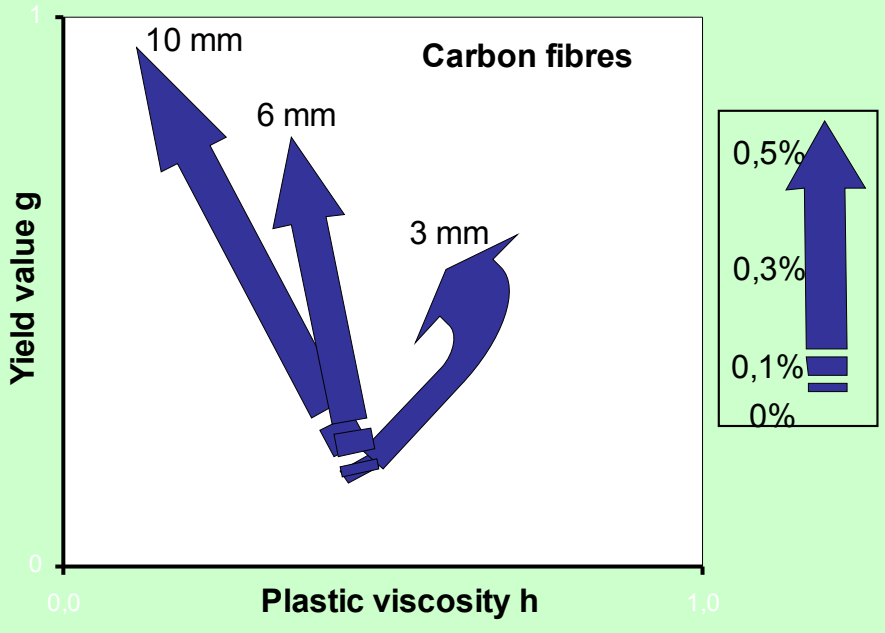
Influence the length and volume fraction of **carbon** fibres on rheological parameters of FRFM; a) W/C = 0.53; b) W/C = 0.50

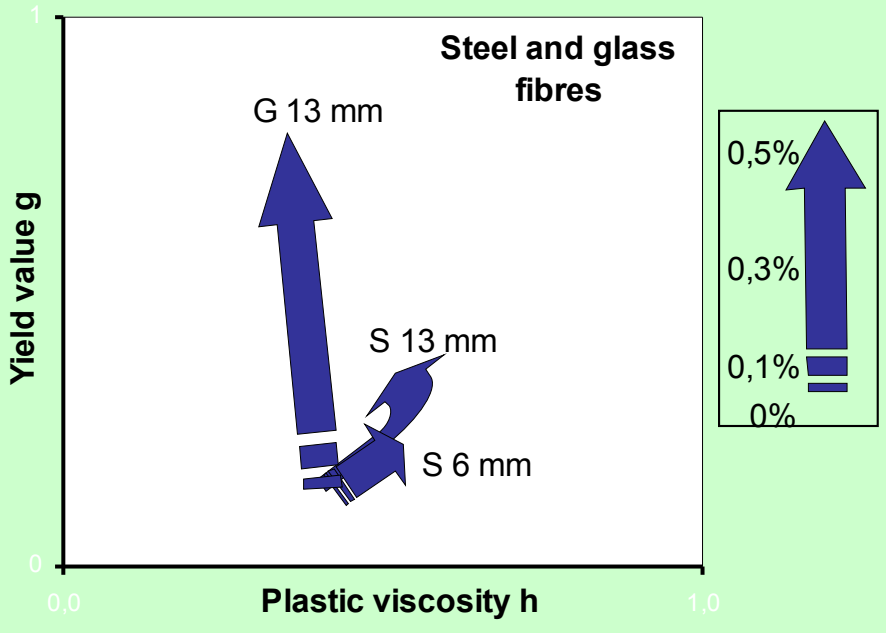





Polypropylene
monofilament fibres
12 mm
6 mm
3 mm
0,5%
0,3%
0,1%
0%
Yield value g
Plastic viscosity h
1
0
0,0
1,0


Polypropylene
fibrillated budles
19 mm
12 mm
6 mm
0,5%
0,3%
0,1%
0%
Yield value g
Plastic viscosity h
1
0
0,0
1,0


10 mm
Carbon fibres
6 mm
3 mm
0,5%
0,3%
0,1%
0%
Yield value g
Plastic viscosity h
1
0
0,0
1,0


Steel and glass
fibres
G 13 mm
S 13 mm
S 6 mm
0,5%
0,3%
0,1%
0%
Yield value g
Plastic viscosity h
1
0
0,0
1,0

CONCLUSIONS - 1

Analysis of variances (ANOVA) of obtained rheological parameters for FRFM showed that:

- type of fibres and fibre volume fraction have the significant influence on yield value **g** but W/C ratio have the significant influence on plastic viscosity **h** of tested **polypropylene** FRFM,
- fibre volume fraction have higher influence than W/C ratio on yield value **g** but W/C ratio have higher influence than fibre volume fraction on plastic viscosity **h** of tested **glass** FRFM,

CONCLUSIONS - 2

- W/C ratio have the significant influence on yield value **g** and W/C ratio, fibre length and fibre volume fraction have the significant influence on plastic viscosity **h** of tested **steel** FRFM,

- fibre volume fraction have the significant influence on yield value **g** but W/C ratio and fibre volume fraction have the significant influence on plastic viscosity **h** of tested **carbon** FRFM,

CONCLUSIONS - 3

- The length of fibres do not have the significant influence on yield value **g** and plastic viscosity **h** of FRFM,

- The significant influence of the length of fibres on plastic viscosity **h** of tested **steel** FRFM was observed only,

CONCLUSIONS - 4

- The rheological properties of **polypropylene fibrillated** and **steel** FRFM from workability point of view are better than for FRFM with other types of fibres,

- In case of **glass** and **carbon** fibres the workability of FRFM worsens with the increase of their volume fraction.