ZAG LJUBLJANA

Department for materials
Laboratory for concrete

Zavod za gradbeništvo Slovenije
Slovenian National Building and Civil Engineering Insti
Dimičeva 12, 1000 Ljubljana, Slovenija

Ljubljana, August 13th, 2003

TRANSLATION OF THE REPORT SUMMARY

No. PP 414/03 - 430 - 2

(replaces the report summary No. PP 414/03 - 430 - 1)

on testing of concrete, reinforced with **FIBRILs** polypropylene fibres

Applicant:	Tekstilna tovarna Motvoz in platno d.d. Grosuplje, Taborska 34, 1290 Grosuplje
Order or contract:	Order No. 1965 of April 4th 2003

Motvoz d.d. Grosuplje produces four types of polypropylene fibres: Fibrillated fibres (FIBRILs F), fire-resistant fibrillated fibres (FIBRILs FFR), monofilament fibres (FIBRILs S) and fire-resistant monofilament fibres (FIBRILs SFR). Fibres are produced in standard lengths 6, 12, 18, 36, 54 and 66 mm, on special requests also in other lengths. The use of FIBRILs polypropylene fibres is easy since no problems occur during mixing of concrete. By adding fibres the crack formation in young concrete is reduced significantly (2 to 7-times), the compressive strength is increased by up to 12% and the bending strength by up to 19%. In the measurements performed we received the best results with concrete, where FIBRILs F120 fibres were added. FIBRILs S120 fibres are more efficient in inhibition of cracking then FIBRILs F180.

Table: Decreasing of crack area due to adding of fibres in %

Type of fibres	without fibres	F180	F120	S120
Age of concrete - 3 days	0 %	65 %	94 %	54 %
Age of concrete - 7 days	0 %	57 %	91 %	45 %
Age of concrete - 14 days	0 %	50 %	85 %	63 %

Detailed description of testing and results contains the report No. P 414/03–430–2.

Prepared by:
Marjan Japelj, univ.dipl.fiz.

ZAVOD ZA GRADBENIŠTVO SLOVENIJE LJUBLJANA 15

Head of laboratory:
Marija Simon, univ.dipl.inž.grad.

Director:
prof.dr. Miha Tomaževič, univ.dipl.inž.grad.

Department of Materials
Laboratory for Concrete

Ljubljana, Slovenia, 13/08/2003

REPORT

No. P 414/03 – 430 – 2

(substitutes for report no. P 414/03 - 430 - 1)

On testing concrete, micro-reinforced with polypropylene fibres **FIBRILs**

Client:	Tekstilna tovarna Motvoz in platno d.d. Grosuplje, Taborska 34, 1290 Grosuplje, Slovenia
Order/contract:	Order form no. 1965, of 04/04/2003

Project Holder:
Marjan Japelj, BSc in Physics

Head of Laboratory:
Marija Simon, BSc in Civil Engineering.

General Manager:
prof. dr. Miha Tomaževič, BSc in Civil Engineering

1. Introduction

Motvoz d.d. Grosuplje produces four types of polypropylene fibres: Fibrillated fibres (FIBRILs F), non-flammable fibrillated fibres (FIBRILs FFR), monofilament fibres (FIBRILs S) and non-flammable monofilament fibres (FIBRILs SFR). The fibres are produced in standard sizes of 6, 12, 18, 36, 54 and 66 mm, and in other custom made sizes.

On 21 March 2003 we received fibres FIBRILs F180, F120 and S120; 1 kg of each type. On 22 April 2003 we produced 4 specimens of concrete (data in Table 1). From each type of concrete we produced 7 test specimens – 3 cubes for testing compressive strength and measuring density, 3 prisms for measuring flexural strength and a disc for monitoring the development of plastic shrinkage and formation of cracks. The consistency of fresh concrete was examined by measuring slump according to the system SIST EN 12350-2:2001.

2. Preparation of the concrete

We prepared 4 concrete specimens – one without fibres (control) and 3 specimens with different types of fibres. The basic recipe of concrete was the same in all four specimens (Table 2). The fibres were mixed at the same time as the aggregate. The mixing lasted for 90 seconds or until the aggregate was visually completely mixed. The slump of freshly mixed concrete was 80 mm.

Table 1: Marks of concrete specimens

Specimen mark	Fibre content/ (kg/m^3)	Fibre type	Date of mixing
B30477	0	-	22/4/2003
B30478	0.95	F180	22/4/2003
B30479	0.95	F120	22/4/2003
B30480	0.95	S120	22/4/2003

Table 2: Basic concrete recipe – with and without fibres

Basic materials	%	kg/m^3	dm^3
cement Anhovo CEM 42,5 Spec.		340	113
water (W/c = 0,52)		177	173

Super plastificator Kemament FM	1.2	4.1	3.7
Aggregate	%	kg/m^3	dm^3
0/4 - crushed Hotič (type of sand)	50	970	350
4/8 – pebble Hotič (type of sand)	20	386	140
8/16 - pebble Hotič (type of sand)	30	580	210

3. Implementation and results of the test

3.1 Compressive strength and density of hardened concrete

The test specimens in the shape of the cube with the side length of 15 cm were removed from moulds after 24 hours and were stored until testing in an air conditioned chamber at (20±2) °C and over 95 % relative air humidity. Compressive strength was tested at the age of 28 days by using the standard SIST EN 12390-3:2002. For this we used the measured dimensions of cubes. In accordance with the standard SIST EN 12390-7:2001 we defined the density of hardened concrete from the measured dimensions and weigh of test specimens. The results are rounded up to 0.5 MPa or 10 kg/m^3 and shown in the Table 3.

Table 3: Compressive strength and density of test specimens

Specimen mark	a / mm	b / mm	h / mm	m / kg	F / kN	f_c / MPa	D / (kg/m^3)
B30477/1	150.4	150.9	151.5	8.23	1105	48.5	2390
B30477/2	150.3	150.7	151.4	8.31	1044	46.0	2420
B30477/3	150.5	150.8	151.5	8.27	1073	47.0	2410
B30478/1	149.7	149.9	152.5	8.22	1193	52.0	2400
B30478/2	150.5	149.6	149.9	8.23	1098	49.0	2440
B30478/3	149.4	150.0	152.3	8.24	1130	49.5	2410
B30479/1	149.8	149.9	151.3	8.33	1225	54.0	2450
B30479/2	150.0	149.5	151.5	8.27	1208	53.5	2440
B30479/3	149.8	149.7	151.2	8.30	1146	50.5	2450
B30480/1	149.8	150.0	149.8	8.03	1061	47.0	2380
B30480/2	149.6	149.5	149.9	8.10	1108	49.5	2420

B30480/3	150.0	149.7	149.9	8.04	1110	49.5	2390

3.2 Flexural strength

To define the flexural strength of concrete we made three prisms from each type of concrete with dimensions 400×100×100 mm^3. After 24 hours we removed them from moulds and stored until testing in an air conditioned chamber at (20±2)°C and over 95 % relative air humidity. The test was performed at 28 days of age of concrete according to standard SIST EN 12390-5:2001; however, we measured the speed of increment of flexion of the prism instead of speed of increment of force. This was 0.1 mm/min and is typical for testing micro-reinforced concrete (see standards ASTM C1018-97 or JSCE-SF4), where we monitor the toughness of material beside its flexural strength (therefore the curve force-flexion after first crack in the concrete).

The flexural strength test was performed with loads with one third increments (Figure 1). Tensile strength at flexion or flexural strength (f_{cf}) was calculated from the braking force with the formula:

$$f_{cf} = \frac{F \cdot l}{b \cdot h^2},$$

where

F is the highest measured force in kN,

b width of test specimen in mm,

h height of test specimen in mm,

l span between the supports in mm.

The dimensions of the prism were measured right on breaking surface, individual measurements of flexural strength are shown in the Table 4 and rounded to accuracy of 0,1 MPa.

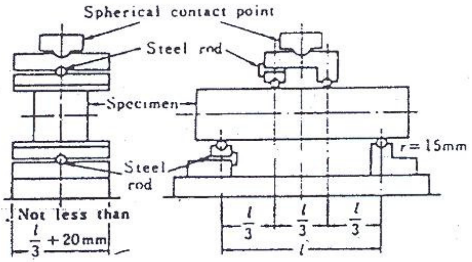


Figure 1: Schematic of loading and supporting of micro-reinforced prism

Table 4: Results of flexural strength test

Specimen mark	b / mm	h / mm	F / kN	f_{cf} / MPa
B30477/4	100.4	99.5	14.5	4.4
B30477/5	100.4	100.8	13.6	4.0
B30477/6	101.3	100.3	13.0	3.8
B30478/4	100.4	100.6	15.8	4.7
B30478/5	102.0	100.7	15.4	4.5
B30478/6	101.3	99.6	15.3	4.6
B30479/4	99.1	102.3	16.2	4.7
B30479/5	100.5	99.3	15.4	4.7
B30479/6	102.0	100.8	17.7	5.1
B30480/4	99.7	100.6	14.7	4.4
B30480/5	102.6	99.2	14.0	4.2
B30480/6	102.1	99.6	15.3	4.5

3.3 Observation of plastic shrinkage and widening of cracks

On 22 April 2003 we mixed the concrete for monitoring the development of plastic shrinkage. The test specimens were in the shape of a disk, with inner diameter of 30.5 cm and outer diameter of 68.0 cm (Pictures 2 to 5 in Appendix 1). At the inner rim the disk was fixed to a rigid metal ring that prevents shrinkage of concrete on the inside of the disk. To accelerate the forming of cracks the specimens were exposed to relatively hot and dry climate (Diagram 1). At the age of 3, 7 and 14 days we thoroughly examined the surface of the specimens and marked the new cracks. After 14 days we measured the lengths of cracks, assessed their width and photographed the specimens. The widths of cracks were assessed with a method of measuring the widths of 10 (randomly selected) cracks on each specimen of the same age and averaged the measurements. We obtained the surface area of the new cracks at a certain age by multiplying the lengths of then newly formed cracks with the assessed widths of these cracks. Total surface area of cracks of a given concrete is a sum of surfaces of newly formed cracks at the ages of 3, 7 and 14 days. The results are shown in the Table 5. The Table 6 shows the decrease in crack surface in % in comparison to the concrete without added fibres. Measured average lengths of the cracks were between 4.2 and 4.8 mm for all types of concrete.

Table 5: Surface area of the cracks at different concrete ages

Type of fibres	No fibres	F180	F120	S120
Age of concrete - 3 days	10 mm^2	4 mm^2	1 mm^2	5 mm^2
Age of concrete - 7 days	17 mm^2	7 mm^2	2 mm^2	9 mm^2
Age of concrete - 14 days	34 mm^2	17 mm^2	5 mm^2	13 mm^2

Table 6: Decrease in the surface area of cracks due to added fibres in %

Type of fibres	No fibres	F180	F120	S120
Age of concrete - 3 days	0%	65%	94%	54%
Age of concrete - 7 days	0%	57%	91%	45%
Age of concrete - 14 days	0%	50%	85%	63%

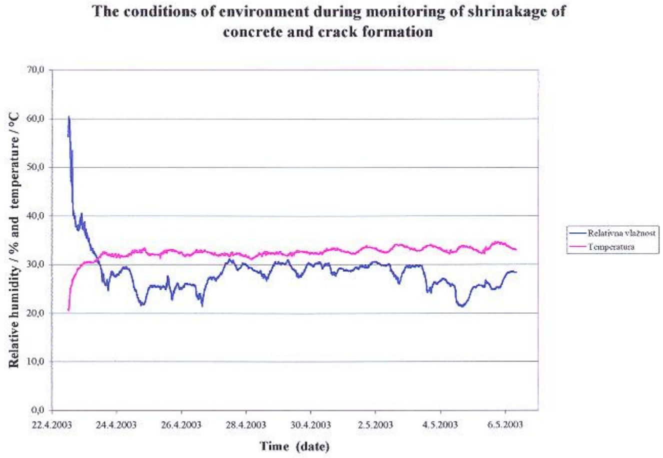


Diagram 1: The conditions of environment during monitoring of plastic shrinkage of concrete and crack formation

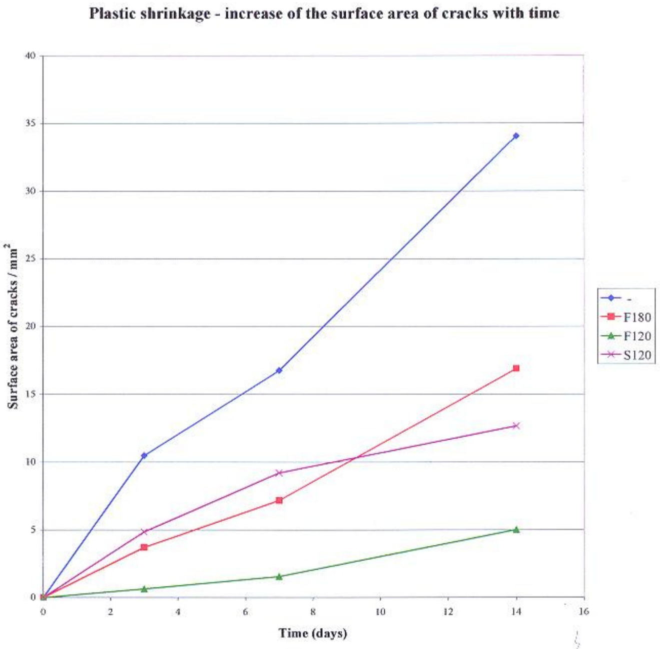


Diagram 2: Surface area of cracks at different ages of concrete

The results of the test refer only to the tested specimens. The report is to be reproduced only in its entirety.

4. Comparison of results

Table 7 shows the comparisons of results of density, compressive strength, flexural strength after 28 days, and surface area of cracks for all 4 tested types of concrete. The shown index is a quotient of average value of measurements for a specific type of concrete, and average value of measurements for control concrete specimen (fibre free).

Table 7: Comparison of results of different concrete types

Specimen	B30477	B30478	B30479	B30480
Type of fibres	-	F180	F120	S120
Density / (kg/m^3)	2410	2420	2440	2400
Index	1.00	1.00	1.02	1.00
Compressive strength / MPa	47.0	50.0	52.5	48.5
Index	1.00	1.07	1.12	1.04
Flexural strength / MPa	4.1	4.6	4.8	4.4
Index	1.00	1.12	1.19	1.07
Surface area of cracks at 14 days / mm^2	34	17	5	13
Index	1.00	0.50	0.15	0.37

The above table shows that all the shown parameters a correlated. The specimen with fibres F120 stands out, for its density is a bit higher in comparison with the rest of the specimens. The increase in compressive strength of micro-reinforced concretes in comparison with control concrete is between 4 and 12%, the increase of flexural strength is between 7 and 19%. The substantial increase can be observed in the crack formation in fresh concrete, for the micro-reinforced concrete contains 2- to 7-times less cracks that the control concrete without fibres.

5. Conclusion

The use of polypropylene fibres FIBRILs is simple, for they do not cause any problems when mixing into concrete. Added fibres considerably decrease the formation of cracks in young concrete (2- to 7-times), while they increase compressive strength up to 12% and flexural strength up to 19%. The performed measurements provided the best results in the concrete to which we added fibres FIBRILs F120. The fibres FIBRILs F120 are much more effective in preventing cracks then fibres FIBRILs F180.

6. Appendices

1. Pictures of specimens during monitoring of plastic shrinkage (8 pictures - 4 pages)

Report prepared by: Marjan Japelj, BSc in Physics

Monitoring of plastic shrinkage and formation of cracks: after 3 days

after 7 days

after 14 days

Picture 2: Concrete without fibres

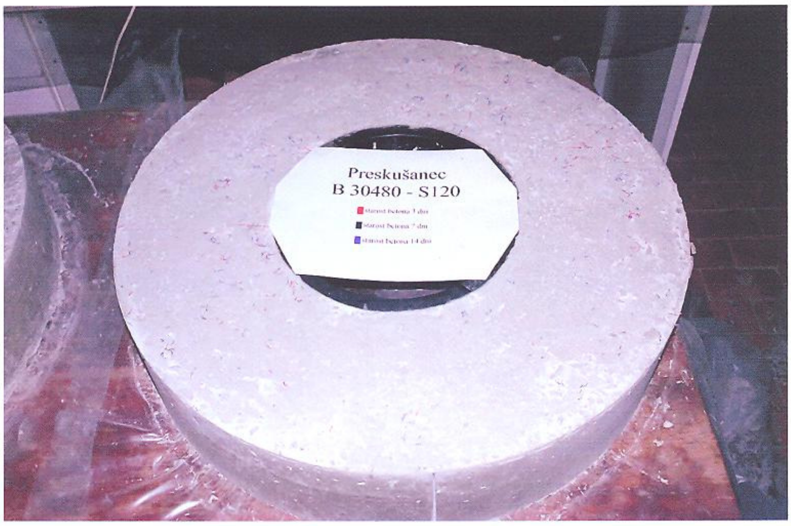
Picture 3: Concrete with fibres FIBRILs F180 – 0.95 kg / m^3

Monitoring of plastic shrinkage and formation of cracks: after 3 days

after 7 days

after 14 days

Picture 4: Concrete with fibres FIBRILs F120 – 0.95 kg / m^3

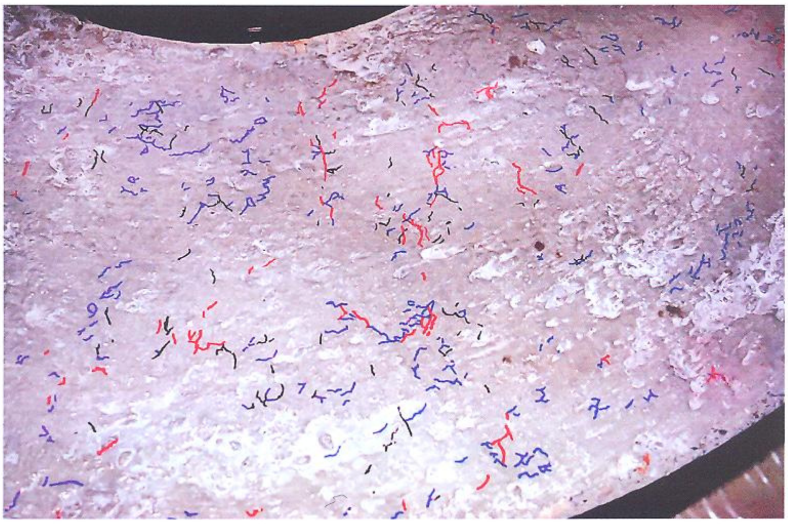


Picture 5: Concrete with fibres FIBRILs S120 – 0.95 kg / m^3

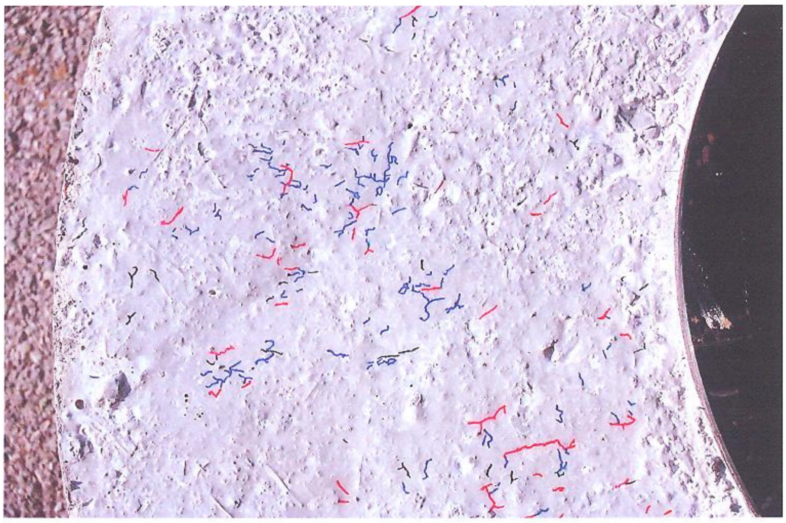
Monitoring of plastic shrinkage and formation of cracks: after 3 days

after 7 days

after 14 days



Picture 6: Concrete without fibres – surface detail



Picture 7: Concrete with fibres FIBRILs F180 – 0.95 kg / m^3 – surface detail

Monitoring of plastic shrinkage and formation of cracks: after 3 days

after 7 days

after 14 days