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Procedia Engineering 181 (2017) 285 – 292

Procedia Engineering

www.elsevier.com/locate/procedia

10th International Conference Interdisciplinarity in Engineering, INTER-ENG 2016

Practical Applications of Dispersely Reinforced Concrete with Polypropylene Fibers: Beams

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Abstract

The practical applications of dispersely reinforced concrete with polypropylene fibers are various; one of them may be achieving concrete beams reinforced by steel bars and dispersely spread polypropylene fibers.
The paper presents some practical tests showing the combined effect of steel and fibers reinforcement over the bending load bearing capacity, the shear strength and deformations for concrete beams. The test results could represent a small contribution to the development of knowledge in the dispersely reinforced concrete aria using one type of polypropylene fibers, for which the information on their field of application is scarce or missing.

Peer-review under responsibility of the organizing committee of INTER-ENG 2016
Keywords: concrete beams; reinforcement; polypropylene fibers.

1. Introduction

The issue of the continuous concrete performance improvement is one of high interest, given the extremely wide scope of its use in constructions.

The idea of concrete reinforcement using different types of fibers dispersed in its mass is very old, a concrete proof of this being represented by the existence of buildings or parts of buildings made of this material. On the other hand, polypropylene fibers used in concrete are something newer [1].

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Peer-review under responsibility of the organizing committee of INTER-ENG 2016
doi:10.1016/j.proeng.2017.02.391

Polypropylene fibers are of many kinds, also having different uses [2], [3]. Polypropylene fibers include Fibrofor® Multi, some of the cheapest on the market and with a limited area of application [4].

The paper aims to develop the applicability domain of these cheap polypropylene fibers. For this, an experimental program has been made. Two types of concrete beams were executed (long and short beams) for tests on the bending capacity and shear resistance. To obtain different information, the trials were carried on control elements made by normal reinforced concrete and on probes made by dispersely reinforced concrete with polypropylene fibers.

Also, two concrete recipes were used, varying the sand and gravel types. All trials were made in an authorized laboratory, under laboratory conditions.

2. Experimental Program

2.1. Polypropylene fibers of Fibrofor® Multi type

The choice of the fiber type was based not only on the lack of information regarding its limited field of application, but also on other criteria, such as: price per kilogram, fibers quantity recommended by the manufacturer to be added to the mixture, their physical and mechanical characteristics.

Table 1 indicates through comparison three types of polypropylene fibers on the Romanian market. It can be noticed that *Multi* fibers have the poorest physical and mechanical characteristics and the smallest quantity recommended in mixture by the manufacturer; the result being the lowest price on cubic meter of dispersely reinforced concrete with fibers.

Table 1. Characteristics of polypropylene fibers (according to the manufacturer) [5].

	Fibrofor Multi	Fibrofor High Grade	Concrix ES
			
Dosage: minimum	0.6	1.0	2.0
[*kg/m*^{3}] maximum	0.9	6.0	7.5
fire-resistant concrete	2.0	5.0	-
Form	multifilament	fibrillated	structured fibers in bundles
Diameter	34 μm	80 μm	500 μm
Length (+/- 5%)	6.3*mm* (tip 63)	19*mm* (tip 190)	50*mm*
	12.7*mm* (tip 127)	38*mm* (tip 380)	
Density	0.91 *g/cm*^{3}	0.91 *g/cm*^{3}	0.91 *g/cm*^{3}
Resistance to acids / alkali	inert	inert	inert
Tensile strength	300 – 400 *MPa*	400 *MPa*	510 *MPa*
Modulus of elasticity	4900 *MPa*	4900 *MPa*	>10000 *MPa*
Melting point	150°*C*	150°*C*	150°*C*
Colour	white	beige	yellow
Packing	bags 0.9 *kg*	bags 1 *kg*	bags 3 *kg*

2.2. Composition of the concrete used

Before starting the experimental program, it was necessary to establish the preliminary composition of the concrete to be used. To establish the composition of the concrete, the following information must be known [6]:

- the class of concrete: C20/25 class was chosen;
- the characteristics of the elements which will be executed, a fact which implies a specific granulometric curve of aggregates and an appropriate workability;
- the conditions of transportation – transportation was not necessary as the mixing was made where the concrete was placed, in a mixing machine having a holding capacity of 50 litres;
- the conditions of concrete placing – manually, by means of a compacting rod;
- the conditions of hardening – normal, the storage and trial of elements are made in the lab.

Considering all the factors and after preliminary trials were performed, the following concrete compositions were obtained:

Table 2. Composition of the concrete used

		R1 – concrete recipe 2 types	R2 – concrete recipe 3 types
river aggregates	type 0 … 4	1030 kg/m^3	640 kg/m^3
1720 kg/m^3:	type 4 … 8	690 kg/m^3	510 kg/m^3
	type 8 … 16	0 kg/m^3	685 kg/m^3
cement CEM IV/B 42.5N:		390 kg/m^3	390 kg/m^3
water:		220 $litri/m^3$	160 $litri/m^3$
A/C ratio:		0.56	0.41
Plasticizer		no	no
polypropylene fibers Fibrofor® Multi type:		0.9 kg/m^3	0.9 kg/m^3

3. Bending Beams

The beams of reinforced concrete were executed with a rectangular section of 125/200*mm* and a length of 2200*mm*. The reinforcement of beams was made by 2 longitudinal bars of Ø10*mm,* made of PC52 steel on the inferior side and 2 longitudinal bars of Ø8*mm* of PC52 steel on the superior side. The transversal reinforcement was made by OB37 steel straps of Ø6*mm*. For the beams execution, concrete prepared with aggregates of two and three types was used, namely 0 – 4*mm* and 4 – 8*mm* and 0 - 4*mm*, 4 - 8*mm* and 8 - 16*mm*, based on R1 and R2 recipes. To compare the impact of reinforcement with polypropylene fibers, beams of concrete were executed with and without fibers addition.

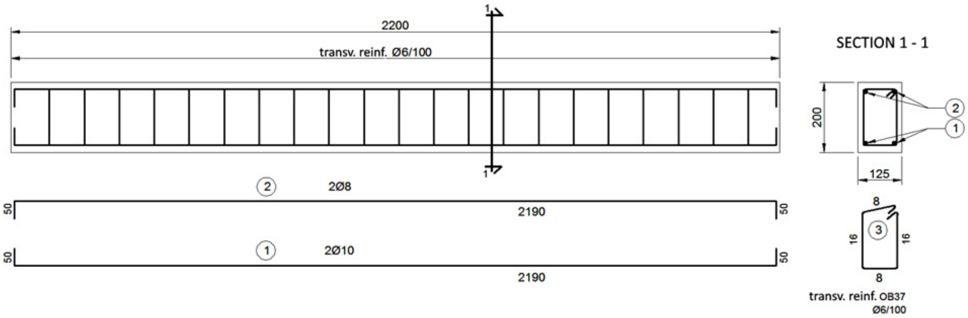

Fig. 1. Concrete form and reinforcement draft for bending beams

The beams were subject to bending on a support especially furnished for this trial. This way, each beam (1) was leaned against two supports (2) located at 2.0*m* distance and a concentrated force was applied upon it at the mid-opening. The force was applied by means of a mobile press (3); in order to be supported, its cylinder was extended by means of a spacer (4) which, at its turn, was set on the beam of the floor in the plant (5) where the trial was performed (fig. 2).

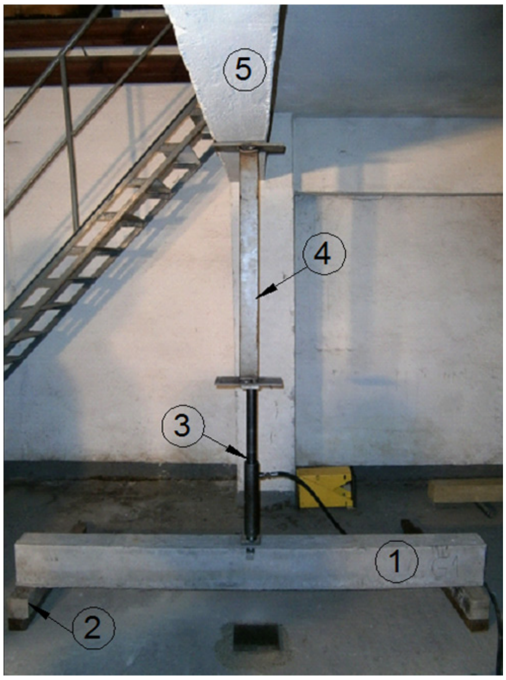

Fig. 2. Support - bending beams trial

The force was applied in steps, each of 2.38*kN*, representing around 10% of the force to which the failure occurred.

The measurement of deformations was performed by a micro-comparator located in the mid-opening of the beam (where force was applied, too). After each step of load, the stability of deformations was waited for (around 5 minutes).

Following the trials, the following aspects were registered:

- G1 beam, made of reinforced concrete without fibers addition (standard sample) failed to a force value of 33.3*kN*; the failure, confirmed by the in-flow of the reinforcement on the inferior side, was preceded by the occurrence of a crack in line with the point of force application; subsequently, other cracks occurred, too, which multiplied under the constant loading [7];
- G2 beam, made of dispersely reinforced concrete with polypropylene fibers, with aggregates of two types, failed to a force value of 35.8*kN*, a value by 7.5% higher than the value of the standard sample; the failure was produced in the same way as in the case of the standard sample; it should be noted that the cracks occurred to a bigger loading, their opening and the distance between them being smaller (fig. 3);
- G3 beam, made of dispersely reinforced concrete with polypropylene fibers, with aggregates of three types, failed to a force value of 38.1*kN*, a value by 14.3% superior to the one of the standard sample; the failure was produced in the same way as in the case of the G2 beam (fig. 3).

Fig. 3. G1, G2, G3 concrete beams and cracks

Table 3. Systematisation of the values obtained following the bending beams trials

Deformation [mm]	Force [kN]												
	7.1	9.5	11.9	14.3	16.7	19.0	21.4	23.8	26.2	28.6	30.9	33.3	35.8
G1	0.13	0.38	0.92	1.42	2.47	3.15	3.89	4.70	6.80	9.14	13.19	-	-
G2	0.36	0.65	1.06	1.68	2.55	3.29	4.39	5.20	6.70	9.35	16.25	20.74	-
G3	0.37	0.68	1.21	1.84	2.62	3.30	4.14	4.75	5.77	7.51	13.80	18.30	21.00

Figure 4 indicates the deformation of the beams at the occurrence of the first crack. It can be observed that the reinforced beams with fibers have larger deformations at the occurrence of the first crack; therefore, the failure is more predictable.

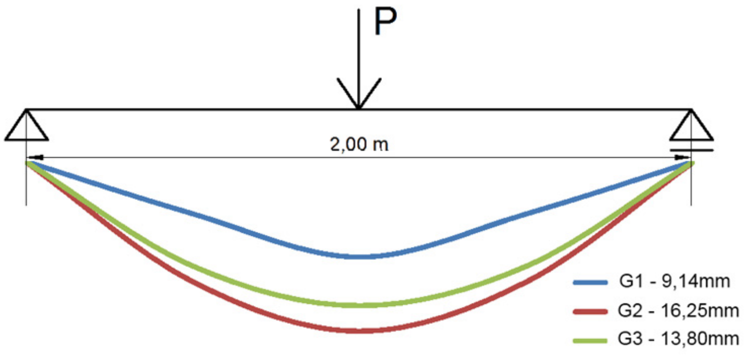

Fig. 4. Deformation of G1, G2, G3 beams at the first crack occurrence

4. Shearing beams

Beams of reinforced concrete were executed, with a rectangular section of 150/250*mm* and a length of 500*mm*. The reinforcement of each beam was made by 2 longitudinal bars of Ø10*mm* made of PC52 steel on the superior and inferior side. The transversal reinforcement was made by OB37 steel straps of Ø6*mm* at 80*mm* distance.

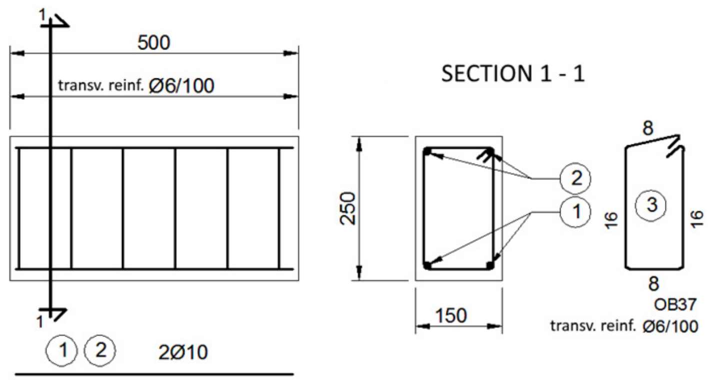

Fig. 5. Concrete form and reinforcement draft for shearing beams

As in the case of the long beams, for these beams too, concrete prepared with aggregates of two and three types were used, according to R1 and R2 recipes. To compare the impact of reinforcement with polypropylene fibers, concrete beams were executed, both with and without fibers addition.

The beams were subject to shearing. For this purpose, they were leaned against the blades of the device attached to the hydraulic press, located at 0.3*m* distance and loaded by a concentrated force, applied upon the mid-opening. The loading was made progressively until failure occurred.

Following the trials, the following aspects were registered:

- GF1 beam, made of reinforced concrete without fiber addition (standard sample) failed to a load value of 254*kN*; the failure was preceded by the occurrence of two inclined cracks, a manner specific to shearing loading; after the cracks occurrence, the process was continued by loading the element until the transversal reinforcement failed, a failure accompanied by a strong noise, specific to steel yielding; afterwards, the avulsion phenomenon of the longitudinal reinforcement could be seen, which was caused by the insufficient anchorage of the steel bars [7];

Fig. 6. GF1 beam between the press platforms (left.) and the moment of the first crack occurrence (right)

- GF2 beam, made of dispersely reinforced concrete with polypropylene fibers, with aggregates of two types, failed to the value of the load force of 264*kN*, a value by 3.9% higher than the value of the standard sample; the failure was produced in the same way as in the case of the standard sample, with the occurrence of a single inclined crack;
- GF3 beam, made of dispersely reinforced concrete with polypropylene fibers, with aggregates of three types, failed to the value of the load force of 280*kN*, a value by 10.2% superior to the one of the standard sample; in this case too, the failure was similar, but more predictable;

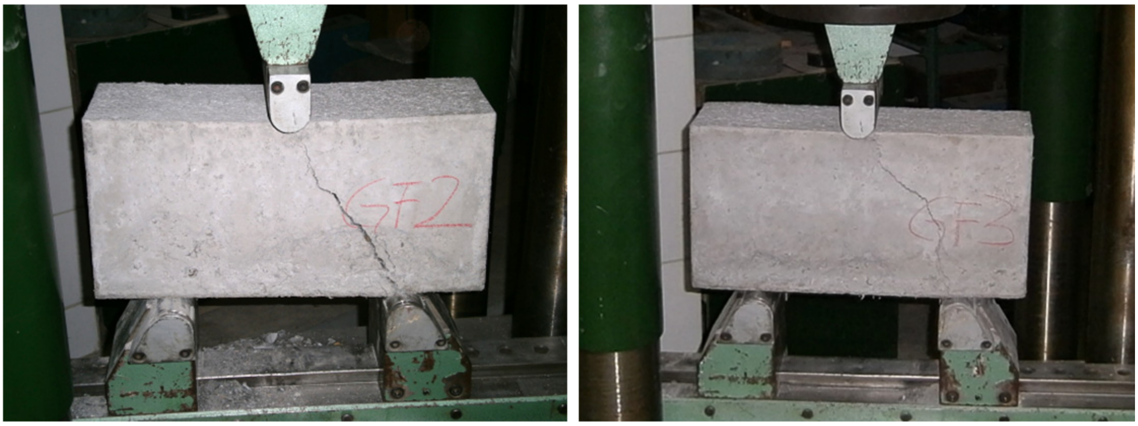

Fig. 7. GF2 and GF3 beams at the moment of the first crack occurrence

- the height of the compressed concrete area at the end of the crack was superior in the case of GF2 and GF3 elements, due to the presence of fibers of disperse enforcement, which improved both the tensile on the inferior side and the compressive strength on the superior side (a fact confirmed by the preliminary laboratory results regarding the compressive strengths of concrete with and without fibers).

5. Results

The bearing property of the reinforced elements with fibers raised in comparison with the bearing property of the elements classically reinforced by a percentage comprised between 3.9% and 14.3%. The reinforcement with polypropylene fibers in combination with the classic reinforcement for the elements prevailingly subject to bending, respectively transverse force, improves their behaviour:

- bigger deformations before the appearance of the first cracks for the beams made by dispersely reinforced concrete;
- the breakage has a more predictable character, as it is not so sudden as it is in the case of the classically reinforced elements;
- the cracks openings and the distance between them were smaller for the concrete beams with polypropylene fibers reinforcement;
- the enhanced concrete adherence of steel reinforcement makes possible a decrease of the anchorage length.

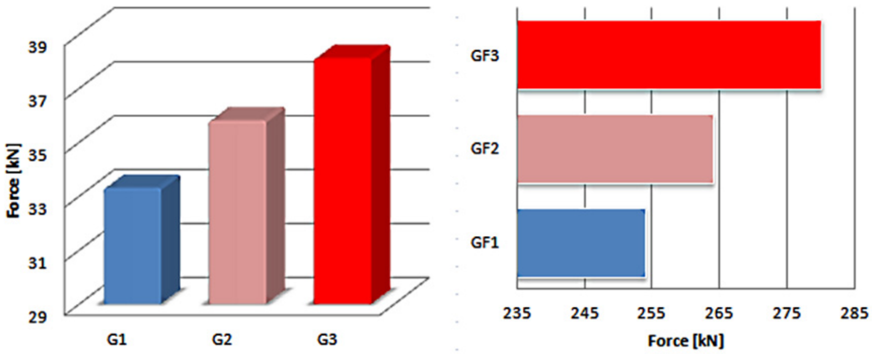

Fig. 8. Bearing property of the three beams at bending (left) and at shearing (right) loads

6. Conclusions

In case of using the dispersely reinforced concrete with polypropylene fibers, after the cracks occurrence, the material maintains a resistance providing an enhanced safety in exploitation. The role of fibers in controlling the cracking process and their quality to maintain the cracked fragments attached, even after an advanced crack, may be beneficially used to elements of reinforced concrete and pre-stressed concrete.

The dispersely reinforced concrete with polypropylene fibers allows the execution of uniform and resistant surfaces and edges and contributes to the decrease of degradations produced when removing concrete forming, on boarders of elements or in the corner areas, and of those likely to occur during the transportation and assembly of prefabricated elements.

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