POSSIBILITIES OF FIBERCEMENT EXTRUSION

PETR TIHLAŘÍK; JINDRA DROTTNEROVÁ; ROMANA SVOBODOVÁ; JIŘÍ BÖHM; JITKA HLEDÍKOVÁ and PAVEL TRČKA

Research Institute of Building Materials, JSC.

ABSTRACT

Extrusion offers a new look at fiber reinforced cementitious composites. By this technology the products of accurate shape and with high performance characteristics may be manufactured. This paper presents the results of research carried out on this technology at Research Institute of Building Materials, JSC Brno.

A mixture for extrusion is typical for its high toughness and high fiber content, as the fiber content may be several times higher than when utilized by other production methods. The technology of a twin shaft kneader makes it possible to produce homogenous mixture for extrusion with low water/cement ratio. With use of auger moulder a mixture of high toughness is formed to final shape. The extreme shear and pressure stress is applied in the process. Therefore high requirements are posed on the equipment.

KEYWORDS:

Extrusion; Fibercement.

INTRODUCTION

Cementitious composites reinforced with fibers are expected to contribute to producing various building materials, which nowadays encourages the development of new mixtures of the composites. The required material properties such as ductility and high strength make them thin and reliable. There are many advantages in manufacturing composite elements by extrusion process. It is easy to make longitudinal ribs which are applicable for manufacturing arch shaped ribbed elements, because the green composite has adequate stiffness to retain its shape and flexibility to be arch-shaped.

During extrusion process the green fibercement paste passes through screw presser and the mouth forms the final shape of the products. There are contradictory requirements on the green mass. It must be adequately fluid but on the other hand the extruded element must retain persistent shape and be manipulatable.

High fiber content was tested. That brought excellent physical-mechanical and termomechanical properties.

TECHNOLOGY EQUIPMENT

The fresh mixture is prepared inside of twin shaft kneader. The kneader enables to prepare homogenous mixture with high fiber content together with low water ratio.

Process of manufacturing begins with homogenising dry components. Addition of water is a second step, and the homogenous cement based paste is prepared. Finally the addition of fibers follows. Fig 1 presents a twin shaft kneader. Once homogenous, the mixture is moulded.by passing through an auger moulder. Its mouth forms the final shape – Fig. 2 and 3. After that the cutting of green products follows. The speed of extrusion may be controlled by frequency converter.

Figure 1 – Twin shaft kneader

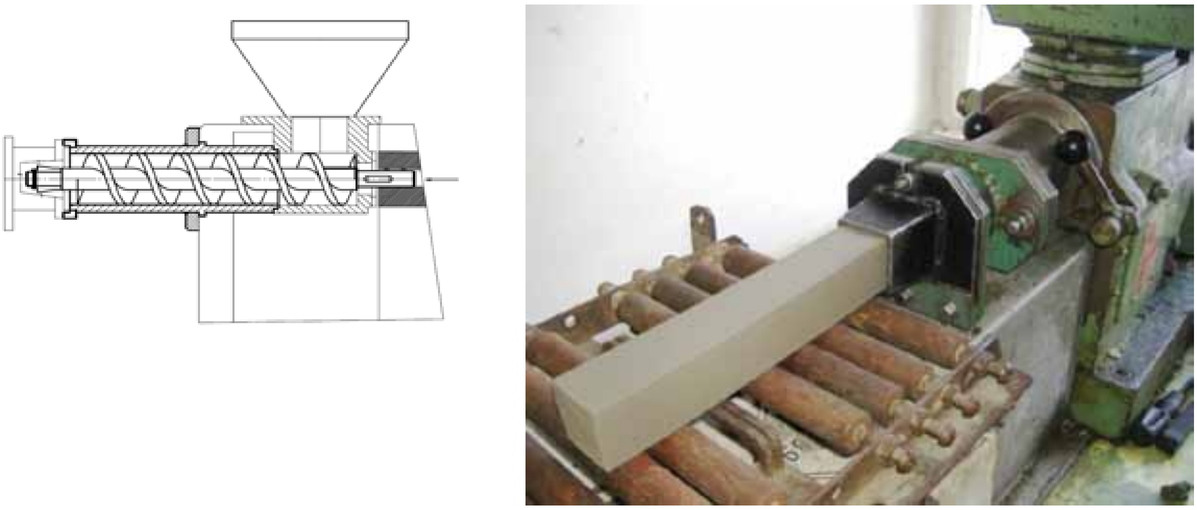

Figure 2 – Screw presser

MATERIAL COMPOSITION

Material base consists of portland cement, fillers, admixtures, agents and fiber reinforcement. Portland cement may be replaced by alumina cement.

The agents provide the green products first of all high stability, thixotropic behaviour, reduction of shape defects, low water ratio and others. They are:

- cellulose ether
- powdered cellulose
- dispersible polymer powder (copolymer of vinyl acetate and ethylene)
- superplasticizer (polycarboxylate based polymer)
- thermoplastic microspheres

Two different types of cellulose ether were employed:

- hydroxyethyl methyl cellulose - HEMC, viscosity 10,4-12,4 Pa.s
- hydroxypropyl methyl cellulose – HPMC, viscosity 5,4-6,6 Pa.s

The minimal amount of different types of cellulose ethers required for successful extrusion process was observed. Lower amount of high viscosity HEMC was required, compared to low viscosity HPMC. The minimum required amount is 0,5% of the cement weight for HEMC and 1% for HPMC.

Mainly the high fiber content was tested. Fiber reinforcement is a crucial constituent which brings excellent physical-mechanical and termomechanical properties.

The effect of addintion of the following fiber reinforcements on extrusion process and on products properties was investigated:

- glass
- carbon
- polypropylene
- steel microfibres
- polyvinyl alcohol
- cellulose
- wollastonite

SHAPED FIBERCEMENT

Extrusion process provides highly shaped fibercement production – Fig. 3. Optimization of material composition, process equipment and manufacturing method brings highly shaped and accurated elements. The following profiles were manufactured in the laboratories of Reseach Institute of Building Materials, JSC:

- Circular profile - inner diameter 20 mm, outer diameter 40mm, wall thickness 10mm
- Circular profile - inner diameter 30 mm, outer diameter 40mm, wall thickness 5mm
- Square profile - width 40mm, wall thickness 5mm

Figure 3 – Extruded fibercement

PROPERTIES

The properties of composite can vary a lot. Material composition and manufacturing process are adept to required application. Table 1 describes glass fiber composite properties. Content of fibres may be up to 12% of the cement weight.

Table 1 – Glass fiber composite properties

Compressive strength	> 40	(MPa)	EN 196-1
Flexural strength	< 30	(MPa)	
Specific gravity	1300 -2100	(kg/m^3)	EN ISO 10545-3
Water absorption	> 3	(%)	
Apparent porosity	< 17	(%)	

Note:

Fiber composites have got high variability of flexural strength. For the value of 34MPa the approx. guaranteed value is 29MPa.

FLEXURAL BEHAVIOUR

The application of fiber reinforcement brings significant increase in residual strength. This effect was most significantly observed on samples with polypropylene fibres. Smaller effect may be observed when steel microfibres are used. In Fig. 4 the flexural behaviour working diagrams with different fiber reinforcement material base content are given.

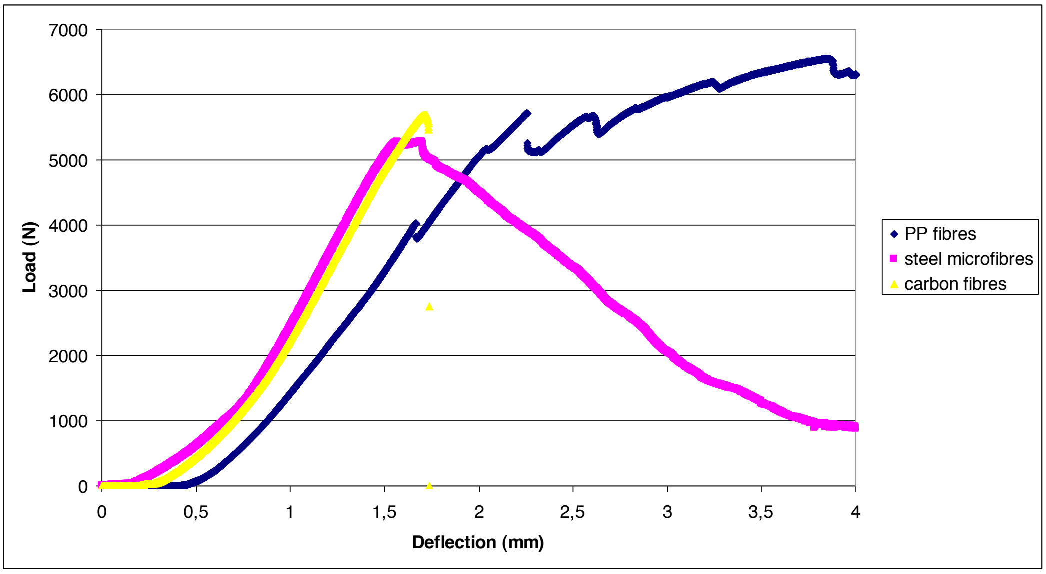

Figure 4 – Flexural behaviour

PLASTICITY OF GREEN MASS

The characterization of rheology is absolutely necessary to develop cement extrusion technology. Test methods which were proposed were initially developed for clay, plastics and rubber.

Two methods for green mass plasticity of dense, cohesive and very dry state were investigated:

1. Shore durometer – The principle: the defined tool point is suspended on defined spring and strain necessary to reach the defined penetrating depth is measured. - ČSN 72 23 48
2. Pfefferkorn apparatus – the deformation of tested body after impact is examined. The ratio of tested body after impact to the body before impact expresses the plasticity – ČSN 72 10 74

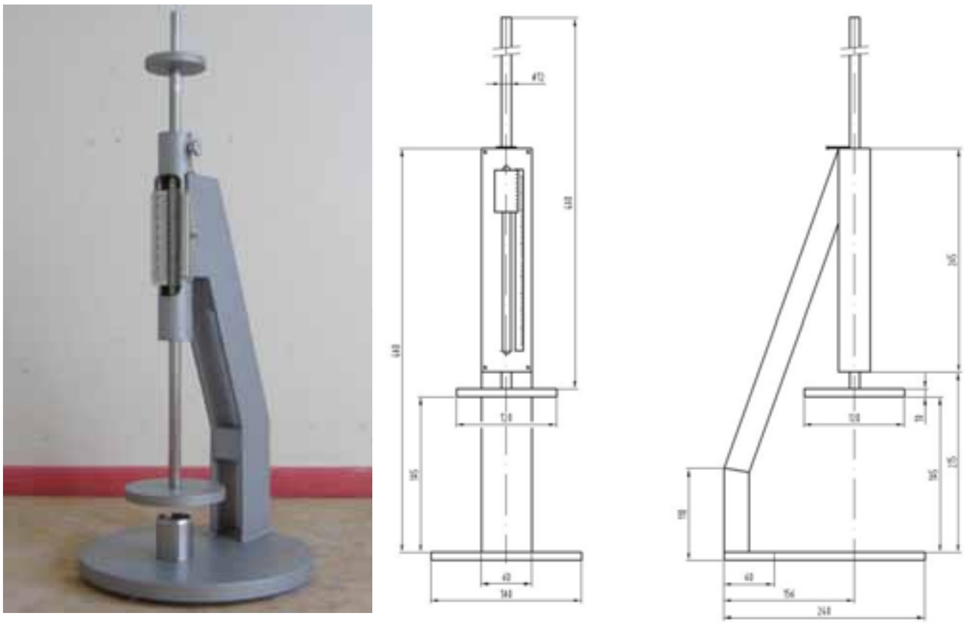

Figure 5 – Pfefferkorn apparatus

Figure 6 – Shore durometer

The correlation between the above methods is given in Fig. 7.

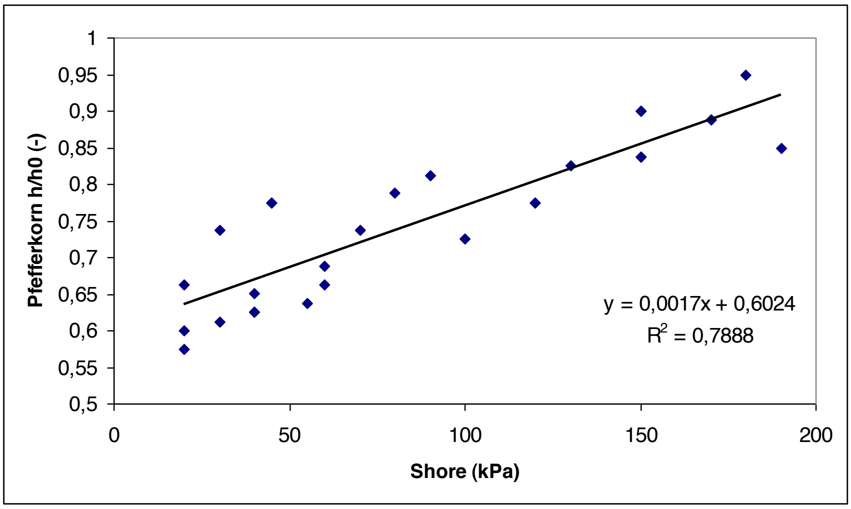

Figure 7 – Correlation curve between Shore and Pfefferkorn

PARTIAL SUBSTITUTION OF HPMC WITH ACTIVATED BENTONITE

HPMC is very price demanding component and that is why there is a trend to minimize its amount. This work studies the partial replacement of HPMC with activated bentonite. The replacing amount of 2% HPMC to referential composition was chosen. Second composition contained 0,5% HPMC and 3% activated bentonite. The reduction in flexural strength, water absorption and apparent porosity by addition of activated bentonite was observed - Table 2.

Table 2 – Substitution of HPMC by activated bentonite

	Flexural strength	Compressive strength	Specific gravity	Water absorption	Apparent porosity
	(MPa)	(MPa)	(kg/m^3)	(%)	(%)
2% HPMC	32,56	52,94	1814	3,7	6,2
0,5% HPMC + 3% activated bentonite	18,98	49,46	1882	10,9	18,9

EXPANSION BY EXTRUSION

The extruded elements are always a little bigger than are the mouth proportions. The reason for this is a high pressure turnover at the end of the mouth. The expansion by using mouth size 40x40 mm was investigated. Average values 41,5 x 41,5mm of extruded elements were achieved. It makes 3,75% expansion. This fact must be taken into consideration when are producing accurated elements.

IMPERFECTIONS BY EXTRUSION

A couple of defects arise by extrusion – Fig 8. The reason may be:

- high toughness
- high opening material content
- high adhesiveness
- high fiber reinforcement content (first of all organic fibres)
- low plasticity

Figure 8 – The Imperfections

TEXTURE AND RECTIFICATION OF FIBER REINFORCEMENT, FRACTURE-MECHANICAL PARAMETERS

Samples with steel fiber content were examined – Fig. 9.

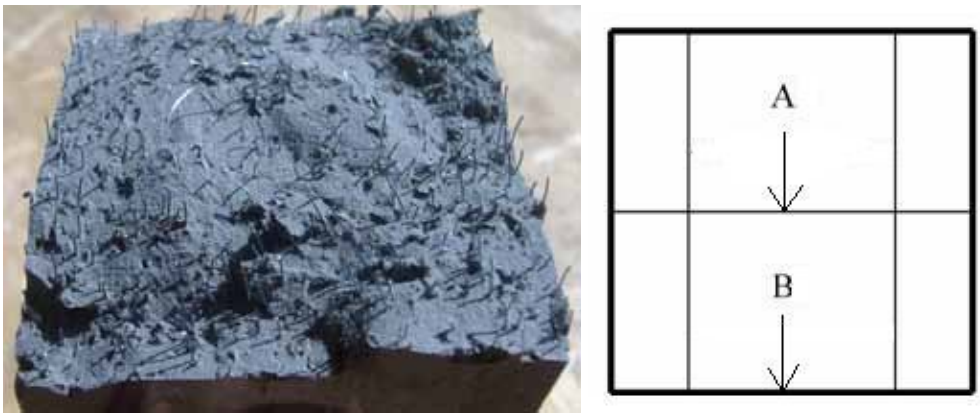

Figure 9 – Fracture of steel microfibres reinforced sample

The values of fracture parameters of the studied composites were determined from tests of specimens loading three-point bending at a constant increment of deflection of 1.5 mm/min. It was possible to record the load–deflection diagram. This diagram was also used to quantify of fracture work and specific fracture energy.

Samples preparation: The samples of the cross-section 40x40 mm were longitudinally cuted and in this way the samples A and B were prepared – Figure 9. The difference between sample A and B was the opposite straining direction. For A the outer area and for B the inner area of sample was pulled.

Table 3 – Fracture-mechanical parameters

sample	fracture toughness	fracture energy
	($MPa.m^{1/2}$)	($J.m^2$)
A	2,30	3387
B	1,18	2009

Sample A (straining outer area) showed much higher values of fracture characteristics. Outer area fibers content is also higher than inner area fibers content. It reveals that the steel microfibres are driven toward the surface of the element by extrusion process.

EFFECT OF MICROSPHERES

The addition of 0,6% thermoplastic microspheres of the cement weight was investigated – Table 4.

Table 4 – Properties of microspheres containing masses

	Water-cement ratio	Flexural strength	Compressive strength	Specific gravity	Water absorption	Apparent porosity
	-	(MPa)	(MPa)	(kg/m^3)	(%)	(%)
referential mixture	0,22	25,49	54,29	1816	3,2	5,4
0,6% thermoplasric microspheres	0,25	10,59	18,98	1307	13,8	17,4

The reduction of flexural and compressive strength was observed, water absorption and apparent porosity were increased. The specific gravity reduction might be more interesting.

CONCLUSION

Extrusion is a well established industrial process, widely used in the field of plastics, metal and clay industry. Despite the great potential of extrusion technology, it has not been widely adopted by fibercement industry so far. Some reasons are offered as rate of production, ease of production, niche market products.

ACKNOWLEDGEMENTS

This paper has been solved in terms of project CIVAK (MŠMT 1M06005).

REFERENCES

Bodnárová, L. “Kompozitní materiály ve stavebnictví” Vysoké učení technické v Brně Fakulta stavební 2002, Brno

ČSN 72 10 74

ČSN 72 23 48

ČSN EN 196-1

ČSN EN ISO 10545-3

Cyr M.F., Peled A., Shah S.P. 2001. “Improving performance of glass-fiber-reinforced extruded composites”. In “Proceedings, 2001 GRC Congress”. Dublin.

Guerrini, G.L. 2005. “Rheological characterisation of cement-based compositions for the extrusion technology”. In “Proceedings, 2005 Cement Combinations for Durable Concrete”. Dundee

http://kureha.com/

http://www.akzonobel.com/

http://www.dow.com/

http://www.haendle.com

http://www.jrs.de/

http://www.krampeharex.com/

http://www.ocvreinforcements.com/

http://www.peramin.com/

http://www.trevos-kostalov.cz/

http://www.wacker.com/

Kuder, K.G., Shah S.P.2006. “Processing of high-performance fiber-reinforced camant-based composites”. In “Proceedings, 2006 IIBCC”. Sao Paulo.

Shao, Y., Marikunte S., Shah S.P. 1995. “Extruded fiber-reinforced composites”. Concrete International, 17 (4) 48-52.

Stang H., Li V.C. 1999. “Extrusion of ECC-material” In “Proceedings, 1999 High Performance Fiber, Reinforced Cement Composites 3”, Mainz.

Volček I.Z., Valjukov E.A.”Ekstruzionyj azbestocement” Moskva Strojizdat Publication 1989, Moscow

Yamada K., Saijo R., Furumura T., Tanaka S. 2006. “Application of Extrusion Molded DFRCC to Permanent Form” In “Proceedings, 2006 International RILEM Workshop on High Performance Fiber Reinforced Cementitious Composites in Structural Applications”.

Řoutil, L., Eliáš, J., Veselý, V., Keršner, Z., Tihlařík, P. & Kněžek, J. Effect of fibres orientation to mechanical/fracture parameters values of extruded cement-based composite. In: CD Proceedings of Conference on *Modelling in Mechanics*, Ostrava, 2010, ISBN 978-80-248-2234-1, in Czech.