EFFECT OF POLYPROPYLENE FIBERS ON MASONRY MORTARS AND PRISMS

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ABSTRACT

The addition of fibers in materials can provide an improvement in their mechanical characteristics. The aim of this work is to evaluate the effect of polypropylene fibers on compressive strength and workability of mortars and, compressive strength of ceramic block masonry prisms and masonry efficiency ratio. Mortar proportions were 1:1:6 (cement:lime:sand - volume percent) and water/cement ratio was adjusted to reach the ideal workability. Six different mortars were formulated with polypropylene fibers from two lengths (12 and 18 mm), types (monofilament and multifibrilated) and ratio (1 and 2%), and one reference mortar (without fibers). Results showed that the addition of the fibers increased mortar compressive strength and also contributed to increase in masonry prisms compressive strength, and, consequently, the masonry efficiency ratio. It was also confirmed that fibers reduce mortar workability.

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INTRODUCTION

Fibrous materials are constituted basically by two phases: the fibers and the matrix in which the fibers are involved. In the case of building materials, matrix are usually fragile (they fail with little plastic deformation), especially pastes, mortars and concrete of mineral binders (REGATTIERI *et al*, 1996).

SILVA *et al* (1990), mentions that fibers with low elastic modulus and high deformation, as polypropylene fibers, have a high capacity of energy absorption.

The principal benefit of the use of fibers is the post-fissuring behavior of the composite. It can avoid the catastrophic failure, exhibiting, eventually, a larger plastic deformation before the rupture.

The aim of this work is to verify the influence of additions of polypropylene fibers on compressive strength of mortars and masonry prisms, and, on the masonry efficiency ratio (ratio between masonry compressive strength and unit compressive strength).

MATERIALS AND METHODS

Compressive strength and water absorption of ceramic structural blocks are respectively 14 MPa and 21%. Sand was washed and can be classified as medium as defined by the Brazilian Standard NBR7211 (1983) and British Standard BS1200 (1976); unit mass and fineness modulus are, respectively, 1.40 kg/dm^3 and 1.69.

The cement was a CP IV-32 type (pozzolanic cement as defined by Brazilian Standard NBR5736, 1991). The lime was a CH III type (magnesia lime as defined by the Brazilian Standard NBR 7175, 1996).

Two kinds of polypropylene fibers were used: monofilament and multifibrilated. Table 1 shows some characteristics.

Table 1- Some polypropylene fibers characteristics.

Material	Polypropylene
Density	0.91 kg/dm^3
Elastic modulus	3500 – 3600 N/mm^2
Tensile Strength	320 – 400 N/mm^2
Alkalis Durability	Excellent

Volume proportions were 1:1:6 (cement:lime:sand), in volume, which represent 1:0,73:8,9 in weight.

One reference mortar (without fibers) and six mortars (with fibers) were formulated, varying the length, the type and the ratio of polypropylene fiber (weight percent relative to cement weight), as described in the Table 2.

Table 2- Mortars with polypropylene fibers.

	Fiber type	Length (mm)	Ratio (weight percent)
$PPMt18_1$	Multifibrilated	18	1
$PPMt18_2$	Multifibrilated	18	2
$PPMn12_1$	Monofilament	12	1
$PPMn12_2$	Monofilament	12	2
$PPMn18_1$	Monofilament	18	1
$PPMn18_2$	Monofilament	18	2

Mortars were made manually. Cement, lime and sand were placed and mixed dry. Then water was added, followed by the addition of the fibers. Water quantity was adjusted to reach the appropriate workability.

For each mortar, consistency was measured with the flow table test, according to the Brazilian Standard NBR 13276 (1995). Twenty days old compressive strength was measured according to Brazilian Standard NBR 7215 (1996).

Three prisms of each mortars with three structural blocks were made with 10 mm joints. Twenty eight days old prism compressive strength was measured according to Brazilian Standard NBR 8215 (1983).

RESULTS AND DISCUSSION

As expected and as it can be seen on Table 3, the fibers addition, independent of the type, length or ratio, leads to a workability decrease and water/cement ratio increase. However, it was noted that addition of fibers increases the mortar cohesion on the holes of the blocks, reducing the losses and, avoiding a supplementary loading of the structure, due to the accumulation of the mortar in the holes of the units.

Comparing monofilament fibers mortars with multifibrilated fibers mortars, it can be seen that the latter reduce water consumption; this is probably due to its higher diameter and lower specific surface (TANESI and AGOPYAN, 1997).

Table 3- Results.

	PPMt 18_1	PPMt 18_2	PPMn 12_1	PPMn 12_2	PPMn 18_1	PPMn 18_2	Reference
Water/cement ratio	2.07	2.26	2.13	2.23	2.18	2.46	1.93
Consistency (mm)	254.50	235.00	268.50	225.00	263.00	243,00	262.50
Mortar compressive strength (MPa)	2.00 ± 0.02	1.90 ± 0.15	1.71 ± 0.29	1.69 ± 0.25	1.41 ± 0.15	1.30 ± 0.13	1.26 ± 0.16
Prism compressive strength (MPa)	4.6 ± 0.23	4.89 ± 0.54	5.14 ± 0.43	4.98 ± 0.23	5.57 ± 0.36	5.29 ± 0.3	4.44 ± 0.26
Masonry efficiency ratio	0.35	0.35	0.37	0.36	0.40	0.38	0.31

Table 4 shows the variation of the mortars compressive strength. Although, the literature contradicts this fact (DANTAS and AGOPYAN, 1988), it can be seen from this study, that polypropylene fibers addition increases mortars compressive strength.

Table 4- Variation of the mortars compressive strength.

	Fiber-modified mortar compressive strength related to reference mortar (%)
PPMt18_1	+ 60,32
PPMt18_2	+ 50,79
PPMn12_1	+ 35,71
PPMn12_2	+ 34,13
PPMn18_1	+ 11,90
PPMn18_2	+ 3,17
Without fibers	Reference

Table 5 gives the variation of the prisms compressive strength formulated with polypropylene fibers mortars. It can be seen that there is a significant increase of the prisms compressive strength molded with the fiber-modified mortars. It was observed that all the prisms break on the same way, i.e. a rupture with vertical cracks parallel to the applied load and, exhibiting a detachment of the faces of the units.

Table 5- Variation of the prisms compressive strength.

	Prisms compressive strength of fiber-modified mortars related to prisms compressive strength of the reference mortar (%)
$PPMt18_1$	+ 11,36
$PPMt18_2$	+ 11,36
$PPMn12_1$	+ 18,18
$PPMn12_2$	+ 13,64
$PPMn18_1$	+ 27,27
$PPMn18_2$	+ 20,45
Without fibers	Reference

According to GOMES (1983), the masonry efficiency ratio for ceramic blocks varies from 0,16 to 0,39. The present study confirmed these results. It was also verified that the addition of the fibers has an influence on the masonry efficiency ratio; it can be noted on Table 6 that there is some variations, principally for the prisms made with the 18 mm polypropylene fiber monofilament mortars.

Table 6- Variation of the prisms masonry efficiency ratio.

	Masonry efficiency ratio for prisms with fiber-modified mortars related to masonry efficiency ratio for the prism with the reference mortar (%)
$PPMt18_1$	+ 12,90
$PPMt18_2$	+ 12,90
$PPMn12_1$	+ 19,35
$PPMn12_2$	+ 16,13
$PPMn18_1$	+ 29,03
$PPMn18_2$	+ 22,58
Without fibers	Reference

CONCLUSIONS

The addition of the fibers to fresh mortar must be done very carefully to ensure that the dispersion and orientation of fibers is homogeneous. According to JOHNSTON (1994), the fibers which are parallel to the composite crack are not very efficient, while fibers which are perpendicular can limit the crack propagation.

Literature states that the addition of polypropylene fibers in cement-based materials doesn’t lead to higher compressive strength (MEHTA, 1994) and, it can be sometimes harmful, due to the excessive formation of air-entraining (ALMEIDA, 1999). In this study, we find the contrary, even if the water/cement ratio must increase with the fiber addition due to the necessity to reach a good workability.

According to METHA (1994), for most of the applications, mortars and concretes containing fibers exhibit a very low consistency. In our study, it was verified that the addition of fibers to the mixture increases the water demand but provided a reasonable consistency, in agreement with the recommendations of the Brazilian Standard NBR 13276 (1995).

The highest mortar compressive strength was obtained with multifibrilated polypropylene fibers.

On the other way, the highest prism compressive strength was obtained with the 18 mm length monofilament polypropylene fibers mortars. According to FIGUEIREDO (1997) apud TANESI *et alli* (1997), increasing the length of the fiber increases the probability of the fiber intercept a crack spread.

Fiber quantity (1 or 2 %) didn't alter significantly mortars and prisms compressive strength. However, according to KRENHEL (1975) apud TANESI *et alli* (1997), the fibers ratio has an important effect on cracking due to shrinkage.

The addition of fibers contribute to the increase of the masonry prism efficiency ratio.

REFERENCES

ALMEIDA, M. O. Estudo da tenacidade e proposta de nova configuração do ensaio de flexão em placas para os concretos reforçados com fibras de aço. 1999. 193 p. Master Thesis – Federal University of Santa Catarina, Florianópolis - SC - Brazil

BRAZILIAN STANDARD, Associação Brasileira de Normas Técnicas. NBR 5637: cimento portland pozolânico, Rio de Janeiro, 1991.

BRAZILIAN STANDARD, Associação Brasileira de Normas Técnicas. NBR 7175: cal hidratada para argamassas, São Paulo, 1986.

BRAZILIAN STANDARD, Associação Brasileira de Normas Técnicas . NBR 7211: agregado para concreto, Rio de Janeiro, 1983.

BRAZILIAN STANDARD, Associação Brasileira de Normas Técnicas. NBR 7215: ensaio de cimento Portland, Rio de Janeiro, 1996.

BRAZILIAN STANDARD, Associação Brasileira de Normas Técnicas. NBR 8215: prismas de blocos vazados de concreto simples para alvenaria estrutural – preparo e ensaio à compressão, Rio de Janeiro, 1983.

BRAZILIAN STANDARD, Associação Brasileira de Normas Técnicas. NBR 13276: argamassa para assentamento de paredes e revestimento de paredes e tetos –

determinação do teor de água para obtenção do índice de consistência padrão, São Paulo, 1995.

BRITISH STANDARD INSTITUTION. BS 1200: sands for mortar for plain and reinforced brickwork, blockwork, blockwalling and masonry, Londres, 1976.

DANTAS F. A. S.; AGOPYAN, V. Adição de fibras em concretos de baixo consumo de cimento – análise da fissuração devido à retração. Boletim IPT, 1988, São Paulo, 12 p.

GOMES, N. S. A resistência das paredes de alvenaria. 1983. 190 p. Master Thesis – Polytechnic School of São Paulo Federal University - SP - Brazil.

JOHNSTON, C. D. Fibre-reinforced cement and concrete. In: V. M. MALHOTRA. Advances in concrete tecnology. 2ª ed. Ottawa: V. M. Malhotra, 1994.

MEHTA, P. K.; MONTEIRO, P.J.M. Concreto: estrutura, propriedade e materiais. Ed. PINI, São Paulo - SP- Brazil, 1994.

REGATTIERI, C. E. X.; SILVA, M. G.; HELENE, P.; AGOPYAN, V.; ABREU, J. V. Estudo de algumas propriedades do concreto reforçado com fibras de aço e polypropylene destinados a pavimentos. In: REIBRAC – IBRACON, 38°, 1996, Ribeirão Preto. Anais..., 1996. v. 1, p. 1-14.

SILVA, M. G.; PRUDÊNCIO Jr., L. R.; FIGUEIREDO, A. D. Utilização de fibras e microssílica em concreto projetado para túneis. ENCO - ENCONTRO NACIONAL DA CONSTRUÇÃO, 10°, 1990, Gramado. Anais.... v. 2.

TANESI, J.; TORNERI, P.; FIGUEIREDO, A. D. de. A influência das fibras de polypropylene na fissuração por retração. In: CONGRESSO IBEROAMERICANO DE PATOLOGIA DAS CONSTRUÇÕES, IV – CONGRESSO DE CONTROLE DE QUALIDADE, VI, 1997, Porto Alegre. Anais... Porto Alegre: LEME-CPGEC/DEC/UFRGS, 1997. p. 273-280.

TANESI, J.; AGOPYAN, V. Compósitos reforçados com fibras plásticas para construção civil. ENCONTRO TECNOLOGIA DE SISTEMAS PLÁSTICOS NA CONSTRUÇÃO CIVIL, II, 1997, São Paulo. Anais... São Paulo: EPUSP, 1997. P. 219-252.