ISSN 2229-5518

Mechanical Properties of Synthetic Fibers Reinforced Mortars

Ahsan Habib[1], Razia Begum[1], Mohammad Mydul Alam[2*]

Abstract-An investigation has been carried out into synthetic fibers (glass, nylon, and polypropylene fibers) effects on the mechanical properties of mortars (cement: sand composition (1:1.5)). Addition of fibers in to the mortars increases the compressive strength of mortar composites except glass fiber. On the other hand, tensile and flexural strength have little influence with the addition of fibers. Increasing the size of the fibers also increases the strength of the mortars but a little extent. Among the fibers, nylon containing mortar composite shows promising mechanical strength that could be easily used as low cost partitioning wall, false ceiling, and other household purpose in the developing countries. We have presented a plausible explanation in accordance with fiber reinforced composite polymer. Other physical properties of the fibers containing mortars were also studied and discussed.

Index Terms-A, Glass, Nylon, Polypropylene, Fiber content, fiber reinforced mortars, synthetic fiber, cement

1 INTRODUCTION

It is known that cementatious materials in the form of mortars or concretes are attractive for using as construction materials. Due to their low price, durability, heavy compressive strength, and stiffness, these materials are using from long time ago as a building materials. Although their tremendous use, some drawbacks (brittleness, poor tensile strength, and moisture movements) were observed from few decades. As a result, scientist and engineers are constantly working to find the solution and to improve the performance of the mortars or concretes. There are some alternatives that can be applied on concrete/mortars to solve the problems however; addition of synthetic fiber is very common because of low cost and to improve the mechanical properties of the mortars (1-3).

Fiber-reinforced mortars (FRM) and concretes (FRC) are a major interesting subject to engineering construction because the addition of fibers to mortars significantly modifies their mechanical properties, such as tensile strength, compressive strength, and toughness [1]. It is important to keep in mind that fibers can reinforce the mortars, if: fibers well dispersed in the mixture, fibers have good mechanical properties and durable in the alkaline cement matrix [1]. There are several reports on the fiber reinforced mortars and cement [2-6]. However, most of the articles were mainly focused on PET fibers (7-15), whereas elastomeric fibers were poorly reported in the literature [16]. Due to lake of studies on elastomeric fiber containing mortars, we have carried out this research and we believe this types of composite will develop building materials and also suitable for developing countries.

[1]*Building Materials division, Housing and Building Research Institute, 120/3, Darus-Salam, Dhaka, Bangladesh. Email: ahbangla@yahoo.com*

[2]*University of Saga, Department of Chemistry, Graduate School of Science and Engineering, Honjo Machi 1, 840-8502,Saga,Japan.Email:mydulalam@hotmail.com*

We mainly used polymeric and glass fibers and observed some anomalous behavior that is also interesting point in this article. We have also tried to explain the role of polymeric fibers to increase the mechanical properties of mortar composites and addressed the anomalous behavior with glass fiber. The main role of the present article is to figure out a high-quality mortar composite that can be beneficial for low income or developing countries as building materials. Additionally effects of the fiber length on the mechanical properties of composites were also discussed.

2 EXPERIMENTAL SECTIONS

2.1 Materials

Fibers: Three types of fibers were used such as, (1) A. glass, (2) nylon, and (3) polypropylene. All fibers were collected from local market except polypropylene. Polypropylene fibers collected from Fiber Mesh Company, USA. All fibers were cut at different sizes such as 0.5, 1.00, and 1.5 inch. Fiber content in mortars was 0.25% - 2.00% by weight of cement + fiber. Typical properties of fibers are presented in Table 1.

Table -1: Typical properties of fibers

Name of fiber	Tensile strength (psi)	Young's modulus ($\times 10^3$ psi)	Ultimate elongation (%)	Specific gravity
Polypropylene	80-110	0.5	25	0.9
Nylon	110-120	0.6	16.20	1.1
A. glass	150-550	10.0	1.5-3.5	2.5

Cement: Ordinary Portland cement (Shah cement brand and conforming to BDS: 232-1993 ASTM: type-1) was used. A single batch was stored and used throughout the experiment. The general composition of cement is presented in supporting material (Table-X).

Sand: Sand was collected from Local River and was used as fine aggregates.

2.2 Methods

In the present investigation the mechanical properties of fiber reinforced mortars were studied with standard methods such as, tensile strength (ASTM C-190), compressive strength (ASTM C-109), flexural strength (ASTM C-221), and water absorption (ASTM C-20).

2.2.1 Preparation of the specimen

The composition of cement and sand was always constant (1:1.5) in mortars. The mortars mixture was prepared manually. After mixing cement and sand, water was added gradually (water cement ratio keeps 0.50). When the mixture becomes uniform, fibers were added slowly to prevent bounding of the fibers. The resulting mixture was then cast into moulds. The specimens were allowed to set during the following 24h and then the moulds were stripped and the specimens were stored under water at room temperature for curing until the test day. Mortars specimens have been cast in brass mould of 2" cube for compressive strength, briquette for tensile strength and 12"×12"×0.5" for flexural strength. All specimens were tested at 28 days using the universal testing machine. Minimum three specimens were tested for accuracy of the data.

3 Results and discussion

3.1 Effect of fiber content and fiber length on the compressive strength of fiber containing mortars composites

Compressive strength is the capacity of a material or structure to withstand axially directed applied forces. When the limit of compressive strength is reached, materials are crushed. Compressive strength is very important for building materials because it indicates the strength of the pillar to resist from fracture. The specimen for compressive strength was prepared according to the experimental section and the data is presented in Table 2.

Table 2 Compressive strength of different fibers containing mortars

Fiber length inch	Fiber content %	Compressive strength (psi)		
		polypropylene	Nylon	A glass
-	0	4480		
0.5	0.5	3920	5600	1792
	1	4592	5712	2240
	2	6720	7056	2352
1	0.5	5600	6384	2688
	1	7056	6272	3163
	2	7280	7056	3248
1.5	0.5	4144	6272	4032
	1	6384	7056	4144
	2	7846	7840	4928

In the present article, we change our fiber length from 0.5 to 1.5 inch and the amount was up to 2 wt% of the total amount (fiber + mortars). In Table 2, we have presented the mechanical strength of different fibers containing mortars composite. Just for a clear comparison with fiber containing mortars, compressive strength of mortars (without fibers) is shown in the Table and the value is 4480. One can easily find that increasing the length and amount of fiber increase the compressive strength of mortars except glass fiber. Closer view can give clear indication that polypropylene (PP) and nylon tremendously increase the compressive strength of mortar composites. On the other hand, addition of glass fiber, decrease the compressive strength a little. It is not straight forward to explain this behavior; however, probable explanation could be similar to the fiber reinforced composite polymer [8-14]. Reinforcement is possible when polymeric fibers in the mortars are well distributed and contributed to bear the applied stress, as a result mortars and fibers together bear the load, similar to stress-transfer mechanism at fiber-matrix interface [14]. Another possibility is that elastomeric fiber increases the plasticity of the composites, and thus composites flow under stress without breaking. Surprisingly, increasing the fiber length also gives good impact on the compressive strength of the composites that is completely opposite behavior compared to fiber reinforced polymer composite [17, 18]. Since glass fiber is more rigid than polymeric fiber, and thus glass fibers could not distribute properly in the composite, as a result composite mortars cannot resist the cracking when stress is applied, as polymeric fiber does.

3.2 Effect of fiber content and fiber length on the tensile strength fiber containing mortars composites

Tensile strength (TS) is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. Tensile strength is the opposite of compressive strength and the values can be quite different. As presented in Table 3, the tensile strength of the mortars without fibers (510 psi) is less than compressive strength (4480 psi).

Table 3

Tensile strength of different fibers containing mortar composites

Fiber length inch	Fiber content %	Tensile strength (psi)		
		polypropylene	nylon	A glass
-	0	510		
0.5	0.5	500	580	400
	1	560	590	420
	2	620	620	430
1	0.5	610	560	400
	1	630	600	410
	2	650	620	440
1.5	0.5	495	570	480
	1	600	600	490
	2	620	620	500

From the Table 3, one can easily comply that glass fibers has no or very little contribution for tensile strength of mortars composites. On the other hand; generally an increasing trends of tensile strength could see with the addition of polymeric fibers. Contrary with the compressive strength, increasing the length of fibers has little impact to the tensile strength of mortars composites. Closer view could explain that small amount of fibers does not change the tensile strength; however, increasing fiber content has good impact on tensile strength of mortar composites. As we already mentioned that addition of fibers increase the plasticity of the composite mortars and hence, tensile strength increases a little extent and beyond this force composite mortars crack. Contrary to the polymeric fiber, glass fiber has no effect on tensile properties of mortar composites because it has no role for increasing plasticity (because glass fiber is rigid).

3.3 Effect of fiber content and fiber length on the flexural strength of fiber containing mortars composites

Flexural strength of a mechanical parameter for brittle material is defined as a material's ability to resist deformation under load. This is also another important for building material to resist from fracture. A clear comparison between the fibers containing mortar composites is presented in Table 4. It is really interesting that addition of fiber with mortars strongly influences the flexural strength. In all the cases an increasing trends have seen. Nonetheless, increasing the size of the fibers also increases the flexural strength, another indication of bearing load simultaneously with fibers and mortars. As we already mentioned that addition of fibers increase the plasticity of the mortars composite and hence an increase trend of flexural strength is observed. Moreover, glass fibers also participate to bear the load and resist from bending of the mortars composite under applied load. Similar behavior was already observed in fiber reinforced synthetic polymer composite [8, 17, 18].

Table 4

Flexural strength of different fibers containing mortars composites

Fiber length inch	Fiber content %	Flexural strength		
		polypropylene	nylon	A glass
-	0	760		
0.5	0.5	999	1190	853
	1	1490	1610	1610
	2	1580	1672	1425
1	0.5	1140	1420	736
	1	1210	1480	1240
	2	1870	1890	1572
1.5	0.5	1150	1370	864
	1	1440	1790	1580
	2	1890	1904	1611

In Fig.1, we present a comparison between different fibers containing mortars so that readers can get easy understanding.

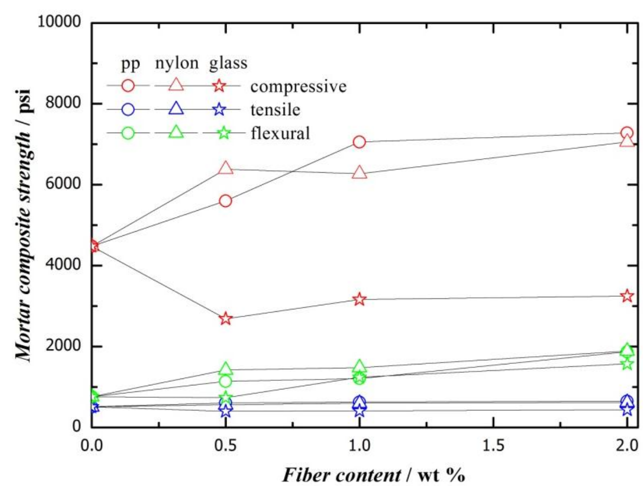

Fig 1: Mechanical properties of different fiber containing mortars; (O) indicates polypropylene fiber, (Δ) indicates nylon fiber, (☆) indicates glass fiber. Red color shows compressive strength, where blue and green color indicates tensile and flexural strength. Fiber length is fixed (1 inch). Readers are requested to use color version for this figures.

Fig 1, clearly indicating that addition of fibers have severe effects on the compressive strength of the mortars composites; however a little effect also could see on tensile and flexural strength. In the previous section, we have already explained that fiber could bear the load with mortars and hence reinforcement happens. Otherwise, fibers will just make some empty space inside the composites and fails to reinforcement [8]. It is clear from the present study that all kinds of fibers are not suitable to increase mechanical strength of the composites.

4 CONCLUSIONS

In the present article, we tried to show a comparative study on the mechanical properties of different fibers containing mortar composites. We also put emphasize on the fibers content and fibers length, because these are also important to contribute the mechanical strength of mortars similarly as type of fibers. In general, the picture could be seen from the present article is that the addition of fiber to the mortars increases the mechanical strength; however dependent on types of fibers; namely elastomeric fibers have good impact on mortar composites, whereas glass fiber does opposite. Increasing fiber content also increases the mechanical strength but fiber length has moderate contribution to the composites. A clear comparison on the mechanical strength of mortar composites among different types of fibers is also presented. This study could be a guide line for the selection of fibers to make high strength mortars composite that could help to the developing countries for building materials.

5 ACKNOWLEDGEMENTS

The authors wish to express their thanks to Dr. Akhtar Uddin Ahmed (principal research officer) for his kind guidance and Mr. Yunus Khan (research associate), Mr. Shah Mostofa (research assistant) for their assistance in the complementation of the work.

6 REFERENCES

[1] Wang Y, Wu HC, Li VC., Concrete reinforcement with recycled fibers, J Mater Civ Eng 2000; 12: 314-19.

[2] Wang Y, Backer S, Li VC, An experimental study of synthetic fiber reinforced cementitious composites, J Mater Sci 1987; 22: 4281-91.

[3] Kim JH, Park CG, Lee SW, Won JP, Effects of the geometry of recycled PET fiber reinforcement on shrinkage cracking of cement-based composites, Compos Part B: Eng, 2008; 39: 441-50.

[4] Silva DA, Betioli AM, Gleize PJP, Roman HR, Gomez LA, Ribeiro JLD. Degradation of recycled PET fibers in Portland cement-based materials. Cem Concr Res 2005; 35: 1741–6.

[5] Oliveira LA, Gomes JP. Physical and mechanical behavior of recycled PET fiber reinforced mortar, Const. Build. Mat. 2011; 25: 1712-17.

[6] Siddique R, Khatib J, Kaur I, Use of recycled plastic in concrete: a review, Waste Manag. 2008; 28: 1835-52.

[7] Choi Y, Moon D, Chung J, Cho S. Effects of waste PET bottles aggregate on the properties of concrete, Cem Concr Res 2005; 35: 776-81.

[8] Ochi T, Okubo S, Fukui K. Development of recycled PET fiber and its application as concrete-reinforcing fiber. Cem Concr Compos 2007;29:448–55.

[9] Kim JHJ, Park CG, Lee SW, Won JP. Effects of the geometry of recycled PET fiber reinforcement on shrinkage cracking of cement-based composites. Compos Part B: Eng 2008; 39(3): 441–50.

[10] Kim SB, Yi NH, Kim HY, Kim JJ, Song YC. Material and structural performance evaluation of recycled PET fiber reinforced concrete. Cem Concr Compos 2010; 32:232–40.

[11] Santos P, Pezzin S, Mechanical Properties of polypropylene reinforced with recycled-PET fibers, J Mat Process Tech 2003; 143-144: 517-20.

[12] Higgins RA, Properties of engineering materials, 2nd Ed., London, p 285, 1994.

[13] Bledzki AK, Gassan J, Natural fiber reinforced plastics. In: *Handbook of Advanced Polymeric Materials*, Cheremisiffon, N.P., Ed. Marcel Dekker Inc.: New York, 1997.

[14] Johnson N, *Synthesis and Toughness Properties of Resins & Composites*, ACCE Composite Structures Tech Conference, Seattle: WA, 1984.

[15] Mohanty A, Misara M, Drzal L, Surface modification and performance of the resulting bio-composites: An overview, Compos Interface 2001; 8: 313-43.

[16] Karnani R, Krishna M, Narayan R, Biofiber-reinforced propylene composites, Polym Eng Sci 1996; 37: 476-83.

[17] Alam MM, Ahmed T, Huque M, Gafur H, Kabir H, Mechanical properties of natural fiber containing polymer composites, Poly Plast Tech Eng 2009; 48: 110-13.

ISSN 2229-5518

Supporting material

Table-X: Composition of cement

Name	Percentage (%)
SiO_2	21.36
CaO	60.82
MgO	3.42
Al_2O_3	3-8
Fe_2O_3	0.5-6
SO_3	1.35
Loss on ignition	2.50
Specific gravity	3.11
Initial Setting time	1hr – 57 min
Final Setting time	2hr 41 min