Research Journal of Applied Sciences, Engineering and Technology 5(18): 4563-4567, 2013
DOI:10.19026/rjaset.5.4375
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: November 08, 2012 Accepted: January 01, 2013 Published: May 05, 2013

Research Article

Experimental Research on the Mechanical Properties of PVA Fiber Reinforced Concrete

[1]Wei Hu, [1]Xingguo Yang, [1]Jiawen Zhou, [2]Huige Xing and [3]Jian Xiang
[1]State Key Laboratory of Hydraulics and Mountain River Engineering,
[2]Colleges of Architecture and Environment, Sichuan University, Chengdu 610065, China
[3]Sino Hydro Bureau 7 CO., Ltd., Sino Hydro Group Ltd., Chengdu, 610081, China

Abstract: This study reports an experimental study on mechanical properties of concrete prepared by polyvinyl alcohol (PVA) fibers. Concrete mixtures are prepared under the same proportions, but by addition of different fibers content. Compressive, splitting tensile and directly tensile tests are carried out for concrete. Primary test results show that, the unit water consumption of mixture was increased with the dosage of PVA fibers, but the slump of concrete mixture was decreased. Experimental results show that, the compressive strength and splitting tensile strength are increased very quickly at the early ages (before the age of 28 days). The compressive strength of concrete is decreased with the increasing of fibers content, but the splitting tensile strength of concrete is increased with the increasing of fibers content. The elastic modulus of concrete was decreased with the dosage of PVA fiber, but the limit tensile strain was increased with the dosage of PVA fiber.

Keywords: Experimental test, fiber reinforced concrete, fiber content, mechanical properties, PVA fiber

INTRODUCTION

Concrete is developing towards high performance, high strength, high toughness, high durability and good studyability since the Portland cement was invented in 1824, to meet the requirements from engineering (Tongaroonsri and Tangtermsirikul, 2009). As a kind of brittle material, the shortcomings of concrete such as low tensile strength, small ultimate elongation and shrinkage are greatly limited the application of concrete (Sun *et al*., 2001; Valeria and Giacomo, 2011). Increasing the ductility and toughness of concrete has been a major motivation for many research studys in recent years (Banthia *et al*., 1996).

However, the disadvantages of plain concrete may be avoided by adding micro-fibers and other materials (Messan *et al*., 2011). Many kinds of fiber are used to enhance the mechanical properties, including polyethylene fiber, Polypropylene (PP) fiber, polyvinyl alcohol (PVA) fiber, carbon fiber, glass fiber and steel fiber, etc (Li *et al*., 1996; Debs *et al*., 2006; Corinaldesi *et al*., 2010). Among all kinds of the fibers, PVA fiber caused more attention because of its good properties such as tensile strength, the similar Young's modulus with the concrete, the thin diameter and bargain price (Schwartzentruber *et al*., 2004; Kou and Poon, 2010). The addition of fibers to a brittle concrete material substantially improves its tensile strength and reduces the tendency of cracking, which leads to enhanced ductility and toughness (Sun and Wu, 2005; Kakooei *et al*., 2012). But if in large quantities, the fibers reduce the study ability of the concrete and reducing its elastic modulus.

The present study performs an experimental study on the mechanical behavior of concrete reinforced with PVA fibers. Four different dosages of PVA fibers are used: 0, 0.9, 1.2 and 1.5 kg/m^3. Compression tests, splitting tensile tests and directly tensile test are carried out for the PVA fiber reinforced concrete. The compressive strength, splitting tensile strength, modulus of elasticity and limit tensile strain of fiber reinforced concrete compared to the plain concrete.

LITERATUR REVIEW

Materials: The cement used was an ordinary Portland cement (P.O. 42.5R). The cement density was 3.09 g/cm^3 and specific surface area was 325 m^2/kg, the compressive strength and flexural strength measured in standard mortar at 28 days were 45.6 MPa and 8.3 MPa, respectively. The fly ash used in this study was supplied by the Mingchuan fly ash Company limited in Guizhou. The fly ash loss on ignition was 5.34%, the water content was 0.2%, and the strength activity index at 7 and 28 are 77 and 88 days, respectively.

In this study, aggregates supplied by Mosagou aggregate system at the Jinping II Hydropower Station, which are manmade by crushed marble. For sand, crushed marble with continuous grading (0-5 mm) were used, the fineness modulus was 2.1, the rock-powder

Corresponding Author: Huige Xing, College of Architecture and Environment, Sichuan University, Chengdu 610065, China

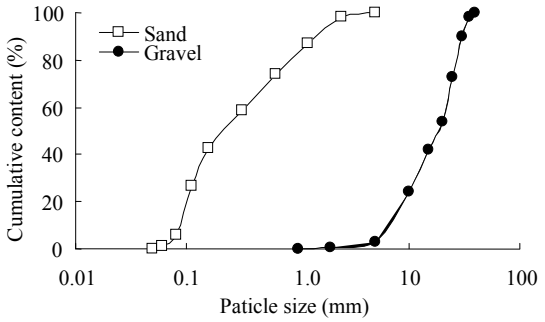

Fig. 1: Grain size distribution curves of the aggregate fractions

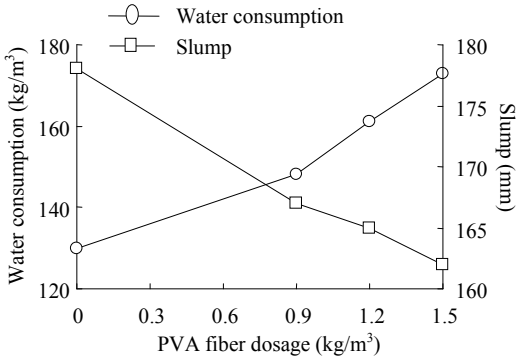

Fig. 2: Water consumption and slump of concrete with different fibers content

Table 1: Main characteristics of the PVA fiber used in this study

Diameter (μm)	Length (mm)	Specific gravity	Young's modulus (GPa)	Tensile strength (MPa)
16.1	12.3	1.29	32.6	1230

Table 2: Proportions of concrete mixture

Mix.		Plain	PVA-0.9	PVA-1.2	PVA-1.5
PVA Fibers	(kg/m^3)	0	0.9	1.2	1.5
Water		129	148	160	172
Cement		258	296	320	344
Fly ash		64.5	74	80	86
Sand		700	673	655	636
Gravel		1300	1250	1215	1182
Slump	(mm)	178	167	165	162

content was 26.8%, and the apparent density 2680 kg/m^3. For gravel, crushed marble with continuous grading (5-40 mm) were used, the apparent density was 2720 kg/m^3 and the water absorption rate was 0.69%. Figure 1 shows the grain size distribution curves of the aggregate fractions.

The PVA fibers used in this study were supplied by Shenzhen Weita Engineering Material Company Limited. They were cylindrical of 12.3 mm length with a nominal diameter of 16.1 μm, the specific gravity was 1.29. The tensile strength of steel fiber was 1230 MPa and the Young's modulus was 32.6 GPa. Table 1 shows the main characteristics of the PVA fiber used in this study.

Mixture proportions: All of the concrete mixes were prepared with a water-cement ratio of 0.40. Four groups of concrete mixtures were studied: one group of plain concreter without any fibers (plain), three groups of concreter with different dosage of PVA fibers, 0.9 kg/m^3 (PVA-0.9), 1.2 kg/m^3 (PVA-1.2) and 1.5 kg/m^3 (PVA-1.5). Table 2 summarizes the composition of the studied concrete.

As showed in Table 2, the gravel with the diameter 5-20 mm and 20-40 mm were used with the ratio 1:1. Figure 2 shows the water consumption and slump of concrete with different fibers content.

As shown in Fig. 2, the unit water consumption of mixture was increased with the dosage of PVA fibers, and the water consumption for plain concrete is 129 kg/m^3. But for PVA fiber-reinforced concretes are all larger than 145 kg/m^3, especially when the dosage of PVA fibers is 1.5 kg/m^3, the unit water consumption is 172 kg/m^3, the increasing ratio of water consumption is about 32.3%. The slump of concrete mixture is decreased with the increasing fibers content. The slumps for plain concrete, PVA-0.9, PVA-1.2 and PVA-1.5 are 178, 167, 165 and 162, respectively.

Test methods: The freshly mix fiber-reinforced concrete was placed in three equal layers into a cubic mold to cast a standard 150×150×150 mm cubical concrete specimen for a compression test or splitting tensile test, and into a 150×150×300 mm prism mold for a directly tensile test. The specimens were cured in a water curing tank at room temperature until the age of 3, 7, 14, 28, 90 and 180 days, respectively were reached.

The test methods for fiber reinforced concrete are in accorded with the standards of CECS 13: 2009. The compressive strength and modulus of elasticity of concrete were determined by the compression tests, the splitting tensile strength was determined by the splitting tensile tests, and the limit tensile strain was determined by the directly tensile tests. The loading rates for compressive strength and splitting tensile strength tests were 300 kN/min and 50 kN/min.

RESULTS AND DISCUSSION

Compressive strength: Compressive strength is one important mechanical characteristics of fiber reinforced concrete. Behavior of concrete in compressive strength was studied at curing time of 3, 7, 14, 28, 90 and 180 days and the results obtained are reported in Fig. 3.

As shown in Fig. 3, the development of compressive of fiber reinforced concrete was similar to the plain concrete. The compressive strength of concrete was increased with the age. The compressive strength was increased very quickly at the early ages (before 28 days) and then slows down after 28 days. The compressive strength of PVA fiber reinforced concrete was lower than the plain concrete, there was a small change in the compressive strength of FRC compare to plain concrete.

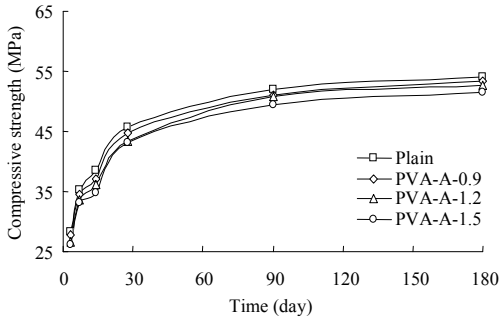

Fig. 3: Compressive strengths vs. curing time

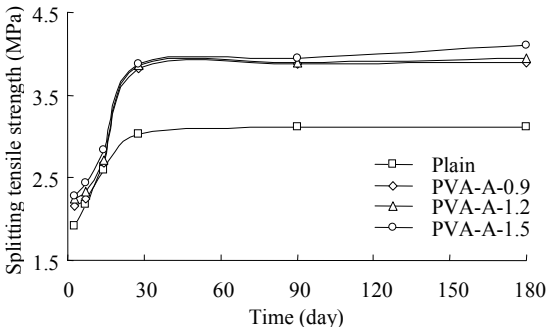

Fig. 5: Splitting tensile strength vs. curing time

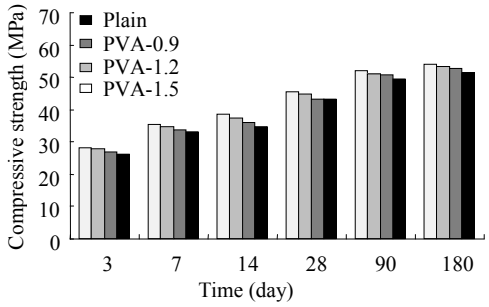

Fig. 4: Fibers content impact on the compressive strength of concrete

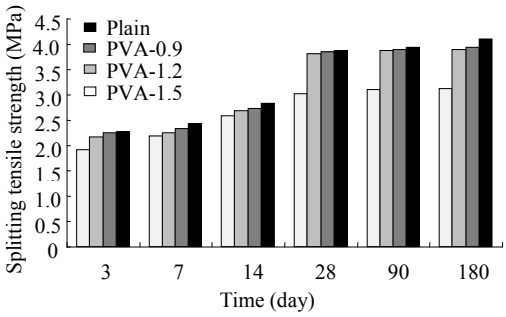

Fig. 6: Fibers content impact on the splitting tensile strength of concrete

Figure 4 shows the fibers content impact on the compressive strength of concrete.

As shown in Fig. 4, the compressive strength of concrete mixture with PVA fiber was decreased with the increasing of fibers content, especially at the early ages of concrete. At the age of 28 days, the compressive strengths of concrete mixtures were decreased about 2.0, 5.1 and 5.5% when the dosages of PVA fibers are 0.9, 1.2 and 1.5 kg/m^3, respectively. At the age of 180 days, the compressive strengths of plain concrete, PVA-0.9, PVA-1.2 and PVA-1.5 were 54.1, 53.3, 52.6 and 51.5 MPa, respectively. The larger amount of PVA fibers addition in concrete will resulted in the lower compressive strength.

Splitting tensile strength: By addition of PVA fibers, the crack propagation in concrete is limited by the fibers, so that the tensile strength of concrete will be improved. Behavior of concrete in splitting tensile strength was studied at curing time of 3, 7, 14, 28, 90 and 180 days and the results obtained are reported in Fig. 5.

As shown in Fig. 5, the splitting tensile strength of concrete was increased with the age. The splitting tensile strength was increased very quickly at the early ages (before 28 days), and then no longer increased after 28 days. The splitting tensile strength of PVA fiber reinforced concrete was larger than the plain concrete, after the addition of PVA fibers into the concrete, because of the crack resistance of fibers, the splitting tensile strength of concrete is increased. At the age of 90 days, the splitting tensile strength of plain concrete, PVA-0.9, PVA-1.2 and PVA-1.5 were 3.11, 3.87, 3.89 and 3.94 MPa, respectively. But at the early ages of concrete, there was a small change in the splitting tensile strength, the splitting tensile strength at the age of 7 days for plain concrete; PVA-0.9, PVA-1.2 and PVA-1.5 were 2.18, 2.25, 2.34 and 2.44 MPa, respectively.

Figure 6 shows the fibers content impact on the compressive strength of concrete.

As shown in Fig. 6, the splitting tensile strength of concrete mixture with PVA fiber was increased with the increasing of fibers content, especially at the later ages of concrete. At the age of 28 days, the splitting tensile strengths of concrete mixtures were increased about 26, 27 and 29% when the dosages of PVA fibers are 0.9, 1.2 and 1.5 kg/m^3, respectively.

Modulus of elasticity: The moduli of elasticity for concrete were calculated at the ages of 28, 90 and 180 days. Figure 7 shows the fibers content impact on the modulus of elasticity for concrete.

As shown in Fig. 7, the elastic modulus of concrete was increased with the curing time and decreased with the dosage of PVA fiber. At the age of 28 days, the elastic modulus of plain concrete is 33.7 GPa, after by addition of PVA fibers, the elastic modulus of concrete were 33.0, 32.1 and 31.2 GPa, respectively. They were decreased 2.1, 4.7 and 7.5%, respectively compared with

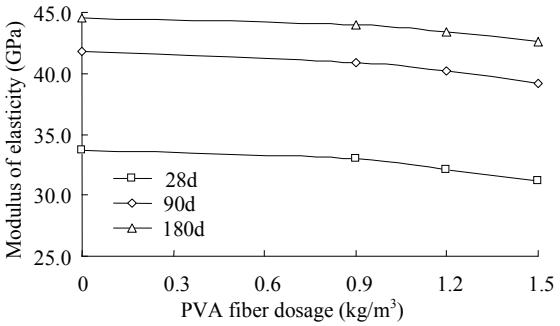

Fig. 7: Fibers content impact on the modulus of elasticity for concrete

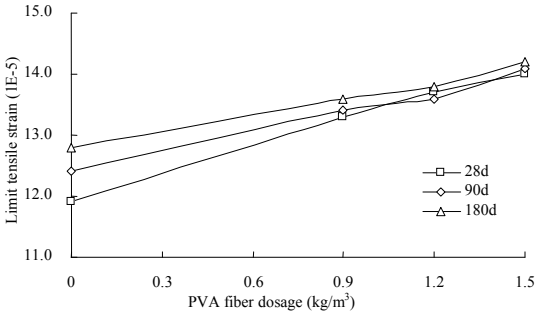

Fig. 8: Fibers content impact on the limit tensile strain of concrete

that of plain concrete. Because of the Young's modulus of PVA fiber is closed to the concrete, but the specific gravity is very little, so that most of the volume is filled with fibers, so that the elastic modulus of concrete is decreased. For the plain concrete, the elastic moduli of concrete were 33.7, 41.8 and 44.5 GPa at the ages of 28, 90 and 180 days.

Limit tensile strain: Limit tensile strain is one important mechanical index for concrete, large limit tensile strain means that the concrete can undergoing a large deformation, but the crack is controlled by the fibers. Figure 8 shows the fibers content impact on the limit tensile strain of concrete. It can be seen that after 28 days, the limit tensile strain of plain concrete mixture was increased, while the concrete mixtures with PVA fiber changed not obviously.

As shown in Fig. 8, the limit tensile strain was increased with the dosage of PVA fiber, after 28 days, the limit tensile strain of plain concrete mixture was increased, while the concrete mixtures with PVA fiber was changed in a small value. At the age of 28 days, the limit tensile strain of plain concrete was 11.9×10^{-5}, and the limit tensile strain were 13.3×10^{-5}, 13.7×10^{-5} and 14.0×10^{-5} when the fiber dosage are 0.9, 1.2 and 1.5 kg/m^3, respectively. The limit tensile strains were increased 11.7, 15.2 and 17.6% compared with the plain concrete when the fiber dosage are 0.9, 1.2 and 1.5 kg/m^3, respectively.

CONCLUSION

In this study, compression tests, splitting tensile tests and directly tensile test are carried out for the PVA fiber reinforced concrete and the mechanical performances are compared for plain concrete prepared by different fibers content. From the results of this comparative experimental study, the following conclusions can be drawn:

- The unit water consumption of concrete mixture was increased with the dosage of PVA fibers, and the slump of concrete mixture was decreased with the increasing fibers content.
- The compressive strength and splitting tensile strength were increased very quickly at the early ages, and then slows down after 28 days. The compressive strength of concrete was decreased with the increasing of fibers content, but the splitting tensile strength of concrete was increased with the increasing of fibers content, especially at the early ages of concrete.
- The elastic modulus of concrete was increased with the curing time and decreased with the dosage of PVA fiber, and the limit tensile strain was increased with the dosage of PVA fiber.

ACKNOWLEDGMENT

The authors wish to thank the helpful comments and suggestions from my teachers and colleagues in State Key Laboratory of Hydraulics and Mountain River Engineering, Sichuan University. This study is supported by the Chinese National Natural Science Foundation (No. 41102194, 51209156) and China Postdoctoral Science Foundation Funded Project (No. 2012T50785).

REFERENCES

Banthia, N., C. Yan and S. Mindess, 1996. Restrained shrinkage cracking in fiber reinforced concrete: A novel test technique. Cement Concrete Res., 26: 9-14.

Corinaldesi, V., G. Moriconi and T.R. Naik, 2010. Characterization of marble powder for its use in mortar and concrete. Constr. Build. Mater., 24: 113-117.

Debs, M.K., L.C. Montedor and J.B. Hanai, 2006. Compression tests of cement-composite bearing pads for precast concrete connections. Cement Concrete Composit., 28: 621-629.

Kakooei, S., H.M. Akil, M. Jamshidi and J. Rouhi, 2012. The effects of polypropylene fibers on the properties of reinforced concrete structures. Constr. Build. Mater., 27: 73-77.

Kou, S.C. and C.S. Poon, 2010. Properties of concrete prepared with PVA-impregnated recycled concrete aggregates. Cement Concrete Composit., 32: 649-54.

Li, V.C., H.C. Wu and Y.W. Chan, 1996. Effect of plasma treatment of polyethylene fibers on interface and cementitious composite properties. J. Am. Ceramic Soc., 79: 700-704.

Messan, A., P. Ienny and D. Nectoux, 2011. Free and restrained early-age shrinkage of mortar: Influence of glass fiber, cellulose ether and EVA (Ethylene-Vinyl Acetate). Cement Concrete Composit., 33: 402-410.

Schwartzentruber, A., M. Philippe and G. Marchese, 2004. Effect of PVA, glass and metallic fibers and of an expansive admixture on the cracking tendency of ultrahigh strength mortar. Cement Concrete Composit., 26: 573-580.

Sun, P.J. and H.C. Wu, 2005. Transition from brittle to ductile behavior of fly ash using PVA fibers. Cement Concrete Composit., 30: 29-36.

Sun, W., H.S. Chen, X. Luo and H.P. Qian, 2001. The effect of hybrid fibers and expansive agent on the shrinkage and permeability of high-performance concrete. Cement Concrete Res., 31: 595-601.

Tongaroonsri, S. and S. Tangtermsirikul, 2009. Effect of mineral admixtures and curing periods on shrinkage and cracking age under restrained condition. Constr. Build. Mater., 23: 1050-1056.

Valeria, C. and M. Giacomo, 2011. Characterization of self-compacting concretes prepared with different fibers and mineral additions. Cement Concrete Composit., 33: 596-601.