© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 11 Issue: 01 | January - March 2020
Paper is available at http://www.jrps.in | Email : info@jrps.in

Review of polyvinyl alcohol (PVA) fibre in cementitious composites: properties and effect

[1]Akash, [2]Satinder Chiller
[1]Research Scholar, Department of Civil, GITM, Jhajjar Haryana
[2]A.P. Department of Civil, GITM, Jhajjar Haryana

Abstract: The effect of uncoated polyvinyl alcohol (PVA) fibre addition on dynamic properties of fibre reinforced concrete (FRC) has been investigated in the current study. PVA fibres of two geometric lengths (6 and 12 mm) with aspect ratio of 428 and 857, respectively, were utilised. Fly ash was also used as partial replacement of Portland cement in all mixes. Based on total concrete volume, two fibre fractions of 0.25% and 0.5% were evaluated for their effect on fundamental frequency, dynamic modulus of elasticity and damping ratio of FRC. 28-Day static mechanical properties are also measured. From the results, it can be stated that although PVA fibre addition in low volume fractions used in this study significantly enhance the mechanical properties of FRC, it has no considerable effect on concrete material damping characteristics.

ISSN : 2278-6848
© International Journal for Research Publication and Seminar

Keyword: Polyvinyl alcohol, ECC, Fibre reinforced concrete

Introduction

The development of polyvinyl alcohol fibre took place in 1939 and is accredited to Dr. Sakuradas and assisting research group of Kyoto Imperial University of Japan. In 1950, Kuraray Corp began to commercially manufacture and sell PVA fibre as the first Japanese organic fibre (Horikoshi, Ogawa, Saito & Hoshiro). The production of PVA is via polymerization of vinyl acetate to polyvinyl acetate (PVAc), pursued by hydrolysis of PVAc to PVA. The chemical structure of PVA is reasonably simple with a pendant hydroxyl group.

To date PVA fibre has multiple uses which include fishing nets, seaweed farming nets, ropes, hoses, belts, tire codes, paper making felts and more. In regards to a cementitious matrix, PVA fibres impose good flexural strength to the composite. This is due to its excellent interfacial bond with the matrix. Refer to Figure 4 for PVA in the form of fibres for use in fibre reinforced concrete. The superb interface characteristic is related to the molecular bond (i.e. hydrogen bond) that is created between the PVA fibre and cementitious matrix during hydration (Scheffler et al 2013). The result is a superior adhesion to the matrix when compared with steel or glass fibres.

Review of literature

(Atahan, Pekmezci, & Tuncel, 2013) studied "Behavior of PVA fiber-reinforced cementitious composites under static and impact flexural effects" and found that the effects of fiber volume fraction and matrix properties on the mechanical performance of 15-mm thick short cut PVA (polyvinyl alcohol) fiber-reinforced cementitious composites were investigated experimentally. Fiber volume ratios of mixtures varied between 0.5 and 2.0% by volume. Two different water to cement ratios (w=c) have been used (0.25 and 0.35) for matrix production. Test results have shown that both fiber content and matrix strength have significant effects on flexural behavior and impact resistance of these composites. The combined effect of w=c and fiber volume fraction on impact resistance was more drastic compared with specific fracture energies of composites determined under static loads. Especially under the effects of impact loads, higher values of w=c and increased PVA fiber content significantly improved the energy absorption capacity of these composites.

(Liu & Han, 2019) studied "Experimental investigation on compressive toughness of the PVA-steel hybrid fiber reinforced cementitious composites" and found that in order to achieve the whole process control of crack formation of engineered cementitious composites (ECC) under loading and improve the mechanical properties of ECC, steel fibers are mixed into traditional ECC to get polyvinyl alcohol (PVA)-steel hybrid fiber reinforced cementitious composites (HyFRCC). And the key parameters to affect the HyFRCC performance are PVA fiber content, steel fiber content, and aspect ratio of steel fiber. In order to investigate the mechanical properties of PVA-steel HyFRCC such as the compressive toughness, 15 PVA-steel HyFRCC specimens with different volume fraction of steel fiber and PVA fiber, together with 1 non-fibrous cementitious composites specimen and 3 ECC specimens with PVA fibers only for comparison were designed and uniaxial compression tests were conducted. Furthermore, the effect of fiber content, fiber type and fiber geometrical characteristic on the compressive toughness of HyFRCC were analyzed. The results show that PVA fiber content, steel fiber content and aspect ratio of steel fiber have little impact on the uniaxial compressive strength of the PVA-steel HyFRCC, while the peak strain, compressive toughness and the post-peak ductility of PVA-steel HyFRCC are improved significantly due to fiber hybridization. The formation of large scale cracks of ECC specimens after post-peak loading is restrained effectively with the addition of steel fiber. The mixture of PVA and steel fiber has a remarkable effect on the improvement of ECC compression toughness and crack control. It indicates that the energy dissipation and damage control capacity of the structural component with PVA-steel HyFRCC under seismic loading will be enhanced.

(J. Zhang, Wang, & Wang, 2017) studied "Properties of polyvinyl alcohol-steel hybrid fiber-reinforced composite with high-strength cement matrix" and found that mechanical properties of polyvinyl alcohol-steel hybrid fiber-reinforced engineered cementitious composite (ECC) with a high-strength cement matrix are experimentally investigated in this paper. Effects of additional steel fibers apart from a constant content of polyvinyl alcohol (PVA) fiber in the composite on compressive, bending, and tensile properties are studied. In the tests, two kinds of cement, ordinary portland cement (OPC) and calcium sulfoaluminate cement (SAC), which possesses extra-high early-age strength, were used respectively as cementing material. The test results show that the cracking and tensile strength of the composites obviously increases with the addition of steel fiber. The additional steel fiber can also increase the tensile strain of the composites. However, a moderate amount of steel fibers (about 1% in the present tests) is needed in order to obtain a positive response on the ultimate tensile strain of the composites. The individual crack width in the multiple cracking stage is significantly decreased with the steel fiber addition. The minimum crack width at tensile strength achieved is about 25 μm. The highest to the lowest compressive and bending strength, tensile strength, and tensile strain and largest and smallest average crack width as tensile strength of the composites achieved at 28 days under normal curing of OPC and SAC series are 99.4-105.37 MPa, 13.91-17.97 MPa, 5.04-8.10 MPa, 0.37-0.82%, 0.089-0.036 mm and 83.75-85.70 MPa, 9.81-15.95 MPa, 4.83-7.32 MPa, 0.51-1.00%, and 0.063-0.025 mm, respectively.

(Atahan et al., 2013) studied "Behavior of PVA fiber-reinforced cementitious composites under static and impact flexural effects" and found that the effects of fiber volume fraction and matrix properties on the mechanical performance of 15-mm thick short cut PVA (polyvinyl alcohol) fiber-reinforced cementitious composites were investigated experimentally. Fiber volume ratios of mixtures varied between 0.5 and 2.0% by volume. Two different water to cement ratios (w=c) have been used (0.25 and 0.35) for matrix production. Test results have shown that both fiber content and matrix strength have significant effects on flexural behavior and impact resistance of these composites. The combined effect of w=c and fiber volume fraction on impact resistance was more drastic compared with specific fracture energies of composites determined under static loads. Especially under the effects of impact loads, higher values of w=c and increased PVA fiber content significantly improved the energy absorption capacity of these composites.

(Meng, Huang, Zhang, & Lee, 2017) studied "Mechanical behaviour of a polyvinyl alcohol fibre reinforced engineered cementitious composite (PVA-ECC) using local ingredients" and found that a polyvinyl alcohol fibre reinforced engineered cementitious composite (PVA-ECC) using local ingredients is developed, aiming for a reduced cost and a tensile strain capacity matching that of steel reinforcement for commonly used reinforced concrete structures. Experiments are conducted to determine mechanical behaviour of the composite. In addition, a finite element model is developed to simulate the flexural behaviour of PVA-ECC beams, and experimental results are used to calibrate the model. The material models of the PVA-ECC under compression and tension are calibrated using experimental results of uniaxial compression and tension tests. Furthermore, a theoretical relationship on the tensile strength between specimens with two-dimensional and three-dimensional fibre distribution is derived, and accuracy of the simulation is improved by using the theoretical ratio. Agreement between the computed results and the experimental data demonstrates the effectiveness of the finite element model.

(Y. Zhang, Zhang, & Liu, 2018) studied "Graphite coated PVA fibers as the reinforcement for cementitious composites" and found that a new preconditioning method was developed to PVA fibers as the reinforcement in cement-based materials. Virgin PVA fibers exhibits limited adhesion to graphite powders due to the presence of oil spots on the surface. Mixing PVA fibers with a moderately concentrated KMnO4-H2SO4 solution can efficiently remove the oil spots by oxidation without creating extra precipitate (MnO2) associated with the reduction reaction. This enhances the coating of graphite powders onto fiber surface and improves the mechanical properties of PVA fiber reinforced concrete (PVA-FRC). Graphite powders yields better fiber distribution in the matrix and reduces the fiber-matrix bonding, which is beneficial in uniformly distributing the stress among embedded fibers and creating steady generation and propagation of tight microcracks. This is evidenced by the significantly enhanced strain hardening behavior and improved flexural strength and toughness.

(P. Zhang, Li, Wang, Shi, & Ling, 2019) studied "Effect of PVA fiber on durability of cementitious composite containing nano-SiO2" and found that

In the current investigation, the influence of polyvinyl alcohol (PVA) fibers on flowability and durability of cementitious composite containing fly ash and nano-SiO2 was evaluated. PVA fibers were added into the composite at a volume fraction of 0.3%, 0.6%, 0.9%, and 1.2%. The flowability of the fresh cementitious composite was assessed using slump flow. The durability of cementitious composite includes carbonation resistance, permeability resistance, cracking resistance as well as freezing-thawing resistance, which were evaluated by the depth of carbonation, the water permeability height, cracking resistance ratio of the specimens, and relative dynamic elastic modulus of samples after freeze-thaw cycles, respectively. The results indicated that addition of PVA fibers had a little disadvantageous influence on flowability of cementitious composite, and the flowability of the fresh mixtures decreased with increases in PVA fiber content. Incorporation of PVA fibers significantly improved the durability of cementitious composites regardless of addition of nano-particles. When the fiber content was less than 1.2%, the durability indices of permeability resistance and cracking resistance increased with fiber content. However, the durability indices of carbonation resistance and freezing-thawing resistance began to decrease as the fiber dosage increased from 0.9% to 1.2%. The fiber reinforced cementitious composite exhibited better durability due to addition of nano-SiO2 particles. Nano-SiO2 particle improves microscopic structure of fiber reinforced cementitious composites, and the nano-particles are beneficial for PVA fibers to play the role of reinforcement in cementitious composites.

Advantages

© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 11 Issue: 01 | January - March 2020
Paper is available at http://www.jrps.in | Email : info@jrps.in

The advantages of PVA fibre usage in cementitious composites to include:

- High aspect ratio (i.e. fibre length to fibre diameter ratio)
- High ultimate tensile strength
- Good chemical compatibility with Portland cement
- Good affinity with water
- Quicker drainage rate
- No risk to health when used

Properties of PVA

The properties of PVA fiber is given below in the table.

Table: Properties of PVA fiber

Types	Density (g/cm^3)	Tensile strength (MPa)	Elastic modulus (GPa)	Diameter (mm)	Length (mm)
PVA fiber	1.2	1,620	42.8	0.039	12
Steel fiber	7.8	2,750	210	0.200	13

Effect of PVA Fibre

The slump flow measurements of the cementitious composite mixtures containing no nano-particles and 2% nano-SiO2 and with different amounts of PVA fiber additions. The figure displays that the slump flow of the mixtures decreased with increasing PVA fiber dosage. The slump flow of fiber reinforced cementitious composite containing 2% nano-SiO2 is lower than that of the fresh cementitious composite containing no nano-particles for the same fiber volume dosage. The decreasing trend in slump flow values may be due to the addition of fibers that created a network structure in the cementitious composite, which restrained the mixture from segregation and flow. In addition, some cement particles may adsorb on the fiber surfaces to wrap the fibers around, thus reducing the amount of effective paste to contribute to the cementitious composite flow.

© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 11 Issue: 01 | January - March 2020
Paper is available at http://www.jrps.in | Email : info@jrps.in

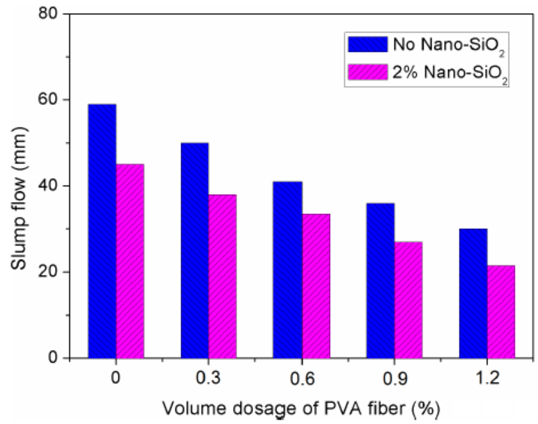

Figure: Effect of PVA fiber on slump flow

The permeability height of cementitious composite specimen generally declined with increasing PVA fiber dosage, which can be seen from Figure 3. Especially after 0.3% PVA fibers were added in the cementitious composite, therewas a sharp reduction in permeability height of the specimen. It is noted that larger amount of PVA fiber addition resulted in larger reduction in permeability height of the specimen.

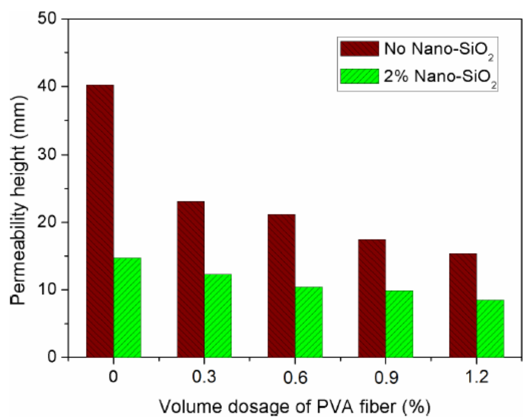

Figure: Effect of PVA fiber on permeability height

Conclusion

Compressive strength at 28 days (fc,28) increases by adding 0.25% PVA fibres to the mix. 11.6% and 7.5% improvement noted in fc,28 is recorded for the mix including 0.25% of 6 and 12 mm fibres, respectively. Accordingly, it can be concluded that shorter fibres increase compressive strength further compared longer-length fibres. However, the compressive strength of PVA-FRCs decreases by adding more than 0.25% PVA fibres. Providing good compaction and dispersion of fibers, increasing PVA volume fraction has a positive effect on the compressive strength of composites, i.e., as the PVA volume fraction increases, the compressive strength increases. Because the shear forces are generated under uniaxial compression loads, PVA fibers can act as numerous tiny reinforcements against shear forces and hold shear plains together.

Bibliography

Atahan, H. N., Pekmezci, B. Y., & Tuncel, E. Y. (2013). Behavior of PVA fiber-reinforced cementitious composites under static and impact flexural effects. *Journal of Materials in Civil Engineering*, *25*(10), 1438–1445. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000691

Liu, W., & Han, J. (2019). Experimental investigation on compressive toughness of the PVA-steel hybrid fiber reinforced cementitious composites. *Frontiers in Materials*, *6*(May), 1–8. https://doi.org/10.3389/fmats.2019.00108

Meng, D., Huang, T., Zhang, Y. X., & Lee, C. K. (2017). Mechanical behaviour of a polyvinyl alcohol fibre reinforced engineered cementitious composite (PVA-ECC) using local ingredients. *Construction and Building Materials*, *141*, 259–270. https://doi.org/10.1016/j.conbuildmat.2017.02.158

Zhang, J., Wang, Q., & Wang, Z. (2017). Properties of polyvinyl alcohol-steel hybrid fiber-reinforced composite with high-strength cement matrix. *Journal of Materials in Civil Engineering*, *29*(7), 1–9. https://doi.org/10.1061/(ASCE)MT.1943-5533.0001868

Zhang, P., Li, Q. F., Wang, J., Shi, Y., & Ling, Y. F. (2019). Effect of PVA fiber on durability of cementitious composite containing nano-SiO2. *Nanotechnology Reviews*, *8*(1), 116–127. https://doi.org/10.1515/ntrev-2019-0011

Zhang, Y., Zhang, Z., & Liu, Z. (2018). Graphite coated PVA fibers as the reinforcement for cementitious composites. *Materials Research Express*, *5*(2). https://doi.org/10.1088/2053-1591/aaad31