THE STUDY ON MECHANICAL PROPERTIES OF VARIOUS FIBER REINFORCED CEMENT-BASED COMPOSITE CEMENTITIOUS MATERIALS

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Abstract. Fiber can improve the bending strength of cement mortar or concrete due to its high toughness. The straw fiber, SF and PF with different properties were mixed into the mortar in the same proportion and different mixing processes to prepare mortar specimens, and the different types of fibers were mixed for the standard curing 7d and 28d. The mechanical properties of the test piece affected the change in this study. The results were shown as follows: the strength of the mortar with straw fiber was higher than that of the post-mixing method, and the flexural strength (referred to as FS) was increased by about 16.0%; the FS of the mortar after the SF was added by 9.7% higher than that of the first blending method, but the compressive strength (referred to as CS) of the first mixed mortar was higher than that of the post-mixing method 16.9%, indicating that the SF had a high modulus of elasticity, which could improve the CS; the growth trend between the FS and CS of the mortar were close with PF. Under the SF first mixing process, the CS was maximized, followed by the PF at the post-mixing method, and the worst was the post-mixing method of the straw fiber.

1. Introduction
The mortar and concrete with cement as the main cementing material have relatively high CS, but the mechanical properties such as bending strength, crack resistance and impact toughness are relatively poor, showing brittleness (JIANG Z., JIN B.H., WANG J.L., 2013). The incorporation of fibers into concrete can improve the brittleness of concrete and expand its application in engineering (LIU W.D., 2010). It has aroused the attention of scholars at home and abroad and achieved certain results. S. Mindess and Vondran G. (1988) investigated that when the volume of polypropylene is 0.5%, the CS can be increased by 25%. A.M.Achozaimy (1996) and others explore the effect of polypropylene fibers (referred to as PF) on the performance of ordinary concrete and concrete added with admixture, showing the impact resistance increasing, and the CS and FS having no effect; the CS of the concrete with silica fume is obviously increased. Luo H.L., et al.(2019)discusses the effects of common polypropylene crude fiber (450μm in diameter) and fine fiber (31μm in diameter) on concrete performance under different aspect ratios.SU A.S., ZENG X.H., DING J.T., et al.(2013)study the CS, tensile strength, FS and flexural toughness of the sprayed concrete when the length-to-diameter ratio was increased. WANG F., WANG B.X., ZHANG Z.Q.(2017) explore that the test piece with 0.3% modified polypropylene fiber and 0.7% steel fiber (referred to as SF) in the concrete has significantly better frost resistance than the two cases such as the 1% of SF test piece and 0.5% of modified polypropylene fiber with 0.5% of SF.
Different types of fibers play different roles in concrete, and the incorporation of fibers leads to increased concrete costs and insufficient stability. Based on three different fibers, this paper discusses the variation of concrete properties in the case of relatively small fiber blending.

2. Raw materials and mix design

2.1 Raw materials

- P.O42.5: it was produced by Lanzhou Jinglan Cement Co., Ltd., the apparent density was 3.10g/cm\(^3\), the specific surface area (SUN D.F., 2012) was 350m\(^2\)/kg, and the fineness was 394m\(^2\)/kg.
- Fly ash: the grade I fly ash was selected from Zhengheng Environmental Protection Engineering Co., Ltd. of Zhengzhou City, Henan Province. It was gray powder, the fineness was 43μm, and the density was 2.4g/cm\(^3\). The chemical composition contained 56.74\% of SiO\(_2\), 24.58\% of Al\(_2\)O\(_3\), 4.87\% of CaO, 6.55\% of Fe\(_2\)O\(_3\), 1.86 of Others.
- Aggregate: the medium-sized Zone II river sand was used for the fine aggregates, the apparent density was 2582 kg/m\(^3\), the packing density was 1648 kg/m\(^3\), and the Fineness modulus (XUE H.J., SHEN X.D., WANG R.Y., et al., 2017) was 3.04.
- Mixing water: it was ordinary tap water.

2.2 Mix design

According to the literature (LI Y., 2011), the mortar has a fly ash content of 30% and the sand-ash ratio of 1:2.5. And the fiber occupied 1% of the mass of all the cementing materials. The mixing ratio of various materials was shown in Table 1.

| Materials                  | Dosage(g) |
|----------------------------|-----------|
| Total mass of cementitious material |           |
| Cement                     | 315       |
| Fly ash                    | 135       |
| Fiber                      | 4.5       |
| Sand                       | 1125      |
| Mixing water               | 229.5     |

3. Test method

3.1 Sample pouring and curing

The fiber was added by the first mixing method and the post-doping method. The mortar was stirred by manual agitation, and the materials were sequentially added to the mixing basin according to the on-site and post-mixing processes referring to the literature (GB/T50080-2002). The manual mixing time was not less than 90 s, no more than 180 s. The fresh mortar was put into the mortar with the standard test mold 40 mm×40 mm×160 mm triple test mold, loaded it twice, level with the size spreader, and vibrate 60 times in the vibrating table, then The mold was filled to the top and then vibrated 60 times to make a test piece (ZHANG L.Q., 2014). After the pouring was completed, the surface of the sample was covered with a plastic film to prevent moisture loss, and then placed in a standard curing box for 24 h, and then the sample was taken out and removed to test time (WANG K., ZHANG H.E., SHI X.S., 2018).

3.2 Flexural strength and compressive strength test

- The flexural strength was tested by using the DKZ-5000 electric folding machine, as shown in Figure 1. Before test, the surface of the test piece should be clean, and the contact surface of the test piece should be ensured.
- The compressive strength were tested by the WEY-3000 microcomputer hydraulic bending pressure testing machine (KANG Y., 2014), shown in Figure 2.
4. Results and discussion

4.1 Mechanical properties change

The straw fiber, SF and PF respectively was added into the mortar by the first doped method (referred to as FDM) and the the after mixing method (referred to as AMM). The Flexural Strength (referred to as FS) and compressive strength (referred to as CS) was tested. The results were shown in Figure 3, Figure 4, and Figure 5.

- The results were showed from Figure 3: the mortar strength was higher at the AMM in both early and late stages. The FS increased by about 16.0% at 7d and 28d. That was to say, the straw fiber could improve the FS of the mortar. The CS of the mortar was about 1.9% higher at 7d and 28d. The straw
fiber exerted the toughness of the fiber, compared with the change of the FS, which greatly improved the bending resistance of the mortar.

- The results were showed from Figure 4: the FS with SF increased by about 9.7% at FDM and AMM in both early and late stages. However, compared with the two mixing methods, the CS of the mortar was 16.9% higher than that of the AMM, indicating that the elastic modulus of the steel fiber was high, which could significantly improve the CS.

- The results were showed from Figure 5: the FS of the mortar added with PF at FDM was about 9% higher than that of the AMM; the CS was high about 8%, which indicated the growth trend between FS and CS was close.

### 4.2 Comparison of the effects of three kinds of fibers on mortar performance

The FS changes were shown in Figure 6, and the CS changes were shown in Figure 7 at 28d.

![Figure 6. The FS changes](image1)

![Figure 7. The CS changes](image2)

- The results were showed from Figure 6: the fibers were added to the mortar with the same amount. When the correlation coefficient $R^2=1$, the fiber content and the strength change were the fifth-order equations, which was solved by the cubic equation. The fiber type used in the highest FS could be obtained. In the CS comparison, the three kinds of fibers would improve the FS of the mortar when the dosage was the same, and the FS was the highest when the same proportion of straw fiber was added.

- Figure 7 showed: the curve was a fifth-order polynomial when the correlation coefficient $R^2=1$. There was a maximum in the CS curve of the three fibers. The maximum value of the mortar was obtained under the FDM of SF, then the PF second, and the smallest was the post-mixing method of straw fiber.

### 5. Conclusions

- The strength of the mortar with straw fiber at FDM was higher than that of the AMM. The FS was increased by about 16.0% at 7d and 28d, and the CS was about 1.9%. Compared with the change of the FS, the straw fiber exerted the toughness of the fiber, which greatly improved the bending resistance of the mortar and significantly improved the brittleness. The FS with SF at AMM was increased by about 9.7%, compared with the FDM; the CS of the mixed mortar was 16.9% higher than that of the AMM, indicating the elastic modulus of the steel fiber was high. The growth trend with PF between the FS and CS of the mortar were close.

- The fibers with different properties were added into the mortar with the same amount. The FS was the highest. There was a maximum value in the CS curves of the three fibers. The SF was firstly mixed to obtain the maximum value of the mortar, followed by the post-blending PF, and the smallest was the straw fiber at AMM.
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