STUDY ON THE EFFECT OF CORN STRAW FIBER ON THE STRENGTH PROPERTIES OF CEMENT MORTAR

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The influence of chemically treated corn straw fibers on the mechanical properties of cement mortar was analyzed, with a focus on quantifying flexural and compressive strength improvements. Corn straw fibers underwent three treatments: ordinary boiling, acetic acid (CH_3COOH), and sodium hydroxide (NaOH). Treated fibers were incorporated into cement mortar at volume ratios of 0.5%, 1%, 1.5%, and 2%, and tested at 7 and 28 days. Results revealed that CH_3COOH-treated fibers enhanced early flexural strength by 41%, achieving a peak of 6.8 MPa at 2% concentration. NaOH-treated fibers showed the best 28-day mechanical performance, with flexural strength reaching 7.93 MPa and compressive strength peaking at 52.1 MPa, 15% higher than the control. Excessive fiber concentrations above 10% negatively impacted strength due to clustering effects. Statistical analysis (ANOVA, $p<0.05$) confirmed the significant influence of treatment methods on mechanical properties. This research demonstrates the potential of corn straw fibers, treated with optimized chemical methods, as a sustainable and efficient reinforcement for cement mortar. The findings contribute to the development of eco-friendly construction materials, and future work should address the long-term durability and the combined effects of multiple treatments.

Keywords: Corn straw fiber, Cement mortar, Mechanical properties, Chemical treatment, Flexural strength, Compressive strength.

1. Introduction

As the global demand for environmental sustainability and the performance requirements of building materials continue to rise, the search for green, eco-friendly, and high-performance building materials has become a hot topic of research. Agricultural waste, such as corn stalks, is considered a potential material for enhancing building materials due to its renewability and environmental friendliness [1,2]. Studies have demonstrated that the incorporation of agricultural by-products, such as digestate, can enhance soil properties and contribute to sustainable material development, showcasing the potential of agricultural waste in green material applications [3].

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Cement mortar, widely used as a binder in the construction industry, plays a crucial role in improving the durability and reliability of building structures. The enhancement of cement-based materials using advanced fibers, such as carbon nanofibers, has shown significant improvements in mechanical properties, highlighting the importance of proper fiber treatment and dispersion methods [4,5]. Similarly, basalt and diatomite-modified composites illustrate how targeted modifications can optimize material performance, offering valuable insights for reinforcing cement mortar with agricultural fibers [6,7,8].

This study aims to evaluate the impact of different chemical treatment methods on the performance of cement mortar reinforced with corn stalk fibers. By systematically varying the amount of fiber added, this study seeks to determine the optimal fiber treatment method and addition amount to maximize mechanical performance. The results will contribute to the development of green building materials by promoting the use of agricultural waste as an eco-friendly reinforcement option.

2. Materials and Methods

2.1 Materials

Cement: P.O. 42.5 cement was selected for this study, meeting national standards. P.O. 42.5 cement is known for its excellent mechanical properties and stability, making it suitable for preparing high-strength cement mortar specimens.

Sand: ISO standard sand was used to ensure consistency and reproducibility in the experiments. ISO standard sand is characterized by its uniform particle size and high purity, making it an ideal choice for preparing cement mortar.

Water: The water used in the experiments was sourced from the tap water of Suihua City, Heilongjiang Province. The low mineral and impurity content in the tap water is unlikely to significantly affect the mechanical properties of the cement mortar.

Corn Straw Fiber: The roots and leaves of the corn straw are removed, leaving only the stalks. The corn stalks are then cut into small sections of 3–5 cm, and the husk and pith are separated using a husk and pith separator, leaving only the corn stalk husks, as shown in Fig. 1. The husks are washed, dried, and then cut into strips measuring 0.5–1.5 × 3–5 cm. Finally, they are crushed using a WKF250 crusher.

Fiber Treatment: Three treatments were applied to the corn straw fibers to modify their properties:

Acid treatment: The corn stalk fiber samples are immersed in a 10% acetic acid solution and treated at 80°C for 4 hours.

Alkali treatment: The corn stalk fiber samples are immersed in a 12% sodium hydroxide solution and treated at 80°C for 4 hours.

Water treatment: The corn stalk fibers are boiled in water for 4 hours.

Fig. 1. Corn stalks after removal of core and pith

2.2 Preparation of Cement Mortar

The cement mortar was prepared using P.O. 42.5 cement with the following mix ratio: 450 g of cement, 1350 g of sand, and 225 g of water. The standard mortar mix ratio was adopted, with cement (450 g ± 2 g), sand (1350 g ± 5 g), and water (225 mL ± 1 mL). Corn straw fiber, treated with different solutions (acid, alkali, or water), was added to the mortar specimens at volume ratios of 0.5%, 1%, 1.5%, and 2% of the standard specimen volume. The density of the corn straw fiber was 5 g/cm³, which was considered to ensure uniform fiber dispersion within the mortar. For each ratio, three 40 mm × 40 mm × 160 mm specimens were prepared.

The specimens were cast in molds and cured in a controlled environment at a temperature of 20°C ± 2°C and a relative humidity of 95% for 24 hours. After demolding, the specimens were stored in a curing room at 20°C ± 2°C and a relative humidity of 95% for the remainder of the curing period (7 days or 28 days, depending on the test). These curing conditions were selected to mimic standard industry practices, ensuring consistency across samples. The mortar mixture ratios are presented in Table 1.

Table 1

Ratio of stalk fiber mortar

Number	Cement (g)	Sand (g)	Water (g)	Cornstalk fibers (g)
A-1	450	1350	225	2.5
A-2	450	1350	225	5
A-3	450	1350	225	15
A-4	450	1350	225	20
AK-1	450	1350	225	2.5
AK-2	450	1350	225	5
AK-3	450	1350	225	15
AK-4	450	1350	225	20
W-1	450	1350	225	2.5
W-2	450	1350	225	5

W-3	450	1350	225	15
W-4	450	1350	225	20

The labels A, AK, and W represent acid treatment, alkali treatment, and water treatment, respectively. For example, AK-2 corresponds to corn straw fiber treated with 1% alkali.

2.3 Statistical Analysis

To assess the significance of different corn straw fiber treatments on the mechanical properties of cement mortar, a one-way analysis of variance (ANOVA) was employed at a significance level of $p = 0.05$. ANOVA was used to compare the mechanical properties across the different treatment groups and identify whether there were significant differences. Post-hoc tests, specifically the Least Significant Difference (LSD) and Bonferroni tests, were performed for pairwise comparisons to determine which specific treatments contributed to observed differences. These tests controlled for Type I errors, minimizing the risk of falsely identifying differences, and provided confidence intervals to ensure the reliability of the findings. This statistical approach provided robust evidence supporting the efficacy of CH_3COOH and NaOH treatments in enhancing cement mortar performance.

3. Experimental Results and Discussion

3.1 Physical Properties of Fiber

After solution treatment, the color of corn straw fibers changed. The color of the corn straw fibers treated with boiling water became slightly lighter, remaining a grayish-yellow overall. The corn straw fibers treated with acid also became lighter, turning white. On the other hand, the corn straw fibers treated with alkali became darker in color, showing a ginger-yellow hue. As shown in Fig. 2 After crushing, the length of the corn straw fibers ranges between 0.5-1.5 cm.

The acid, alkali, and water treatments significantly affect the physical and chemical properties of corn straw fibers. Acid treatment turns the fibers white, indicating effective removal of lignin and other impurities, while alkali treatment darkens the fibers due to structural or compositional changes, and water treatment slightly lightens the fibers by removing soluble impurities [9,10,11].

a: Acid treatment b: Alkali treatment c: Water treatment

Fig. 2. Corn straw fibers after treatment

The fiber length remains within 0.5–1.5 cm, suggesting limited physical damage during the treatments [12]. Alkali treatment enhances fiber properties by removing lignin and hemicellulose, improving the crystalline index and thermal stability, and resulting in fibers with better mechanical strength and water resistance, particularly for composite applications [13,14]. Overall, acid and alkali treatments effectively enhance fiber surface characteristics and bonding performance, making them suitable for various industrial applications [15].

3.2 7-Day Properties of mortars

3.2.1 7-day flexural strength

The experimental results reveal that corn straw fiber treatments significantly affect the early flexural strength of cement mortar specimens. Fig. 3 shows that water- and NaOH-treated fibers generally reduce the early flexural strength of cement mortar, while CH_3COOH-treated fibers consistently enhance it. These results suggest that CH_3COOH treatment is particularly effective in improving the early-stage mechanical properties of cement composites, likely due to the removal of surface impurities, such as lignin and hemicellulose, which enhances the bond between fibers and the cement matrix.

Fig. 4 illustrates the effect of different treatments on the flexural strength of cement mortar. With water treatment, the flexural strength decreases as the fiber content increases, dropping from 5.15 MPa at 0% fiber to 3.8 MPa at 20% fiber.

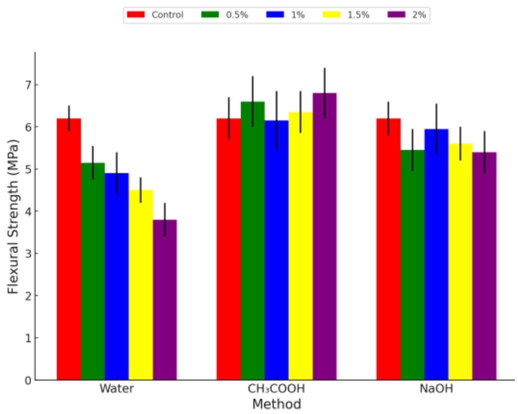

Fig. 3. 7-day Flexural strength of specimens with different treatment methods

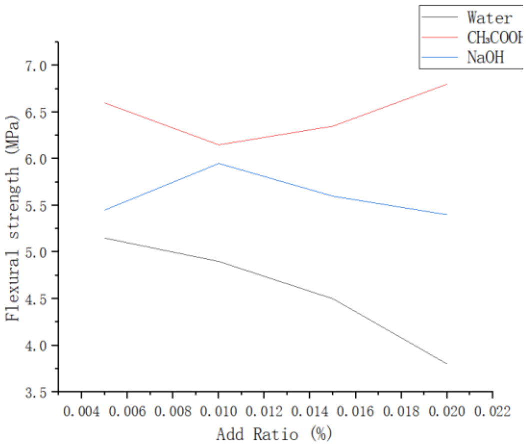

Fig. 4. 7-day strength curves for specimens with different treatment methods

This decline is due to the hydrophilic nature of water-treated fibers, which absorb water during cement hydration, weakening the fiber-matrix adhesion and reducing strength. In contrast, CH_3COOH-treated fibers lead to a steady increase in strength, peaking at 6.8 MPa at 20% fiber content. This improvement is likely attributed to surface modifications that enhance the fiber-matrix bond, reduce void formation, and ensure better structural integrity. For NaOH-treated fibers, the flexural strength fluctuates, reaching a maximum of 5.95 MPa at 10% fiber content, but declining to 5.4 MPa at 20%. This fluctuation suggests that while alkali treatment improves fiber bonding by increasing surface roughness, excessive fiber content at higher concentrations can cause aggregation, reduce workability, and decrease strength.

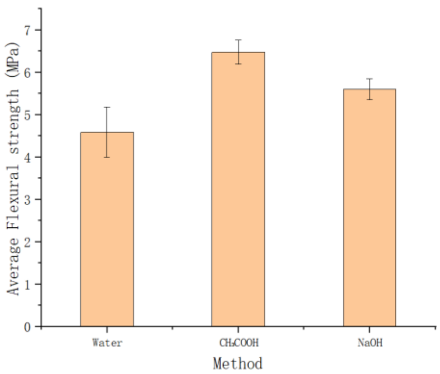

Fig.5. 7-day average flexural strength for specimens with different treatment methods

Fig. 5 shows the 7-day average flexural strength for specimens with different treatment methods. The water treatment results in the lowest average flexural strength of approximately 4.59 MPa, which is consistent with the earlier observation that water-treated fibers negatively affect the bond between fibers and the cement matrix. In contrast, the CH_3COOH treatment yields the highest average flexural strength at approximately 6.475 MPa, suggesting that acid treatment is the most effective in improving early flexural strength due to better fiber dispersion and stronger fiber-cement bonding. The NaOH treatment shows moderate improvement with an average flexural strength of approximately 5.1 MPa, outperforming water treatment but falling short of CH_3COOH-treated fibers. This indicates that while NaOH treatment improves fiber bonding, it also has limitations, especially at higher fiber concentrations, where fiber aggregation can reduce strength.

A one-way ANOVA was conducted to assess the effects of different fiber treatments on the 7-day flexural strength, with results presented in Table 2. The analysis shows that the between-group sum of squares (7.138) is significantly higher than the within-group sum (1.469), yielding an F-value of 21.86, which exceeds the critical threshold $F(2,9) = 4.26$. A p-value of <0.001 confirms that the treatment method has a statistically significant impact on flexural strength.

Table 2

ANOVA Results for 7-Day Flexural Strength

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p-value
Between Groups	7.138	2	3.569	21.860	<0.001
Within Groups	1.469	9	0.163		
Total	8.607	11			

Post-hoc tests using LSD and Bonferroni methods (Table 3) reveal that CH_3COOH-treated fibers significantly outperformed both water-treated (mean difference: 0.875 MPa, $p < 0.05$) and NaOH-treated fibers (mean difference: 1.012 MPa, $p<0.05$). Additionally, NaOH-treated fibers showed highly significant superiority over water-treated fibers (mean difference: 1.887 MPa, $p<0.001$). These results confirm that CH_3COOH treatment is the most effective in enhancing 7-day flexural strength, demonstrating its superior capability to improve early mechanical performance.

Table 3

LSD and Bonferroni Multiple Comparison Results for 7-Day Flexural Strength

Comparison Group	Mean Difference (I-J)	Standard Error	LSD Significance	Bonferroni Significance	Lower CI	Upper CI
W vs A	-0.87500	0.28571	0.014	0.041	-1.7131	-0.0369
W vs AK	-1.88750	0.28571	0.000	0.000	-2.7256	-1.0494
A vs A	1.01250	0.28571	0.006	0.019	0.1744	1.8506

The 7-day flexural strength analysis demonstrates that the treatment method significantly affects the mechanical performance of cement mortar specimens reinforced with corn straw fibers. CH_3COOH-treated fibers achieved the highest average flexural strength (~6.475 MPa), peaking at 6.8 MPa with 20% fiber content, due to the effective removal of lignin, hemicellulose, and other surface impurities, which improved fiber-matrix bonding and minimized void formation [16]. Additionally, CH_3COOH treatment likely enhanced fiber dispersion by reducing hydrophilicity, mitigating the negative effects of fiber aggregation at high concentrations [17]. Water-treated fibers exhibited the lowest average flexural strength (~4.59 MPa), as their hydrophilic nature caused water absorption during cement hydration, weakening interfacial adhesion and increasing microvoids [18]. Despite their poor performance, water-treated fibers serve as a baseline, highlighting the critical role of chemical modifications in improving mechanical properties [10,17]. NaOH-treated fibers showed moderate performance (~5.1 MPa average), with a peak strength of 5.95 MPa at 10% fiber content. The alkali treatment enhanced surface roughness and mechanical interlocking but led to performance reductions at higher concentrations due to fiber aggregation and void formation, consistent with previous studies on alkali treatments [19,20]. Statistical analysis (ANOVA, $p < 0.001$) confirmed the significant impact of treatment methods, with post-hoc tests revealing CH_3COOH-treated fibers significantly outperformed both water- and NaOH-treated fibers. These findings emphasize the effectiveness of acid treatment for early-stage mechanical performance [19,21], while also highlighting challenges related to fiber dispersion at high concentrations.

3.2.2 7-day compressive strength

The experimental results presented in Fig. 6 show that the control group's compressive strength is 33.1 MPa. Water-treated fibers lead to a reduction in compressive strength, declining from 27.5 MPa at 5% fiber content to 16.8 MPa at 20%. This decrease can be attributed to the increased water absorption of the fibers, which weakens the interfacial bond between the fibers and the cement matrix, leading to a reduction in strength as the fiber content increases.

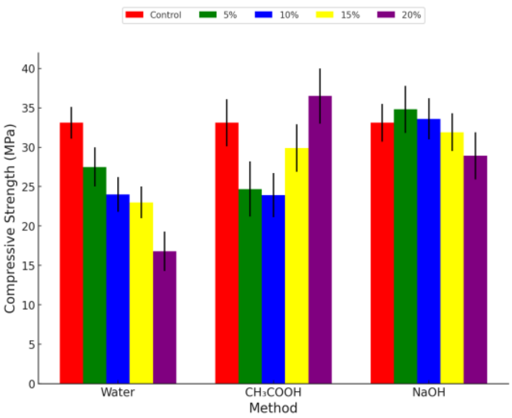

Fig. 6. 7-day Compressive strength of specimens with different treatment methods

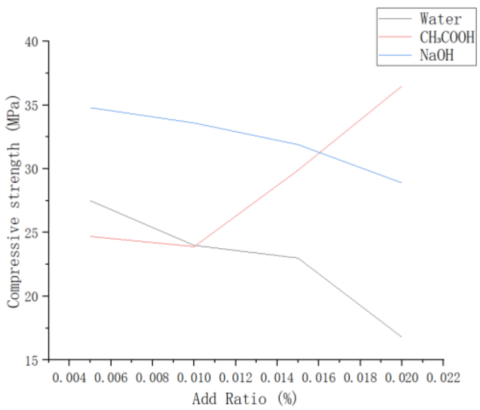

Fig. 7. 7-day compressive strength curves for specimens with different treatment methods

Fig. 7 illustrates that water-treated corn straw fibers show a continuous decline in compressive strength with increasing fiber content. This decline is expected due to the hydrophilic nature of the water-treated fibers, which absorb additional moisture, weakening the bond between fibers and the cement matrix. In contrast, CH_3COOH-treated fibers initially reduce compressive strength at lower concentrations but show a significant increase at 15% and 20%, suggesting an optimal fiber concentration where the treatment enhances the fiber-matrix interaction. This increase in strength could be attributed to improved bonding between the fiber surface and the matrix, as acid treatment removes impurities and enhances fiber dispersion. For NaOH-treated fibers, compressive strength peaks at 34.8 MPa at 0.5% fiber content, surpassing the control, but then decreases steadily to 28.9 MPa at 20%. The strength improvement at lower concentrations is due to the increased surface roughness of the fibers after alkali treatment, which enhances fiber bonding. However, the decline at higher concentrations is likely due to fiber aggregation and poor dispersion, which weakens the material's overall performance.

Fig. 8 shows the average 7-day compressive strength for each treatment type, excluding the control group. The water treatment results in the lowest average compressive strength of 22.83 MPa, which aligns with the earlier observation that water-treated fibers weaken the fiber-matrix bond. In contrast, the CH_3COOH treatment yields an average compressive strength of 28.75 MPa, higher than that of water treatment, indicating that acid treatment effectively improves fiber-matrix adhesion and enhances compressive strength. The NaOH treatment shows the highest average compressive strength of 32.3 MPa, highlighting its superior effectiveness, particularly at lower fiber concentrations, in improving the 7-day compressive performance of the cement mortar.

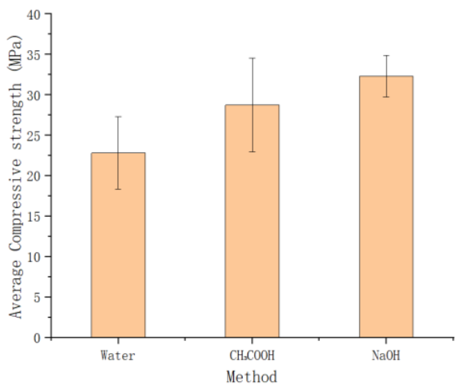

Fig. 8. 7-day average compressive strength for specimens with different treatment methods

An ANOVA was conducted to evaluate the statistical significance of treatment effects on 7-day compressive strength, with results shown in Table 4. The between-group sum of squares (183.312) exceeded the within-group sum (180.538), resulting in an F-value of 4.569, which surpasses the critical value $F(2,9)=4.26$. A p-value of 0.043 confirms that treatment methods significantly affect compressive strength.

Table 4

ANOVA Results for 7-Day Compressive Strength

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p-value
Between Groups	183.312	2	91.656	4.569	0.043
Within Groups	180.538	9	20.060		
Total	363.849	11			

Post-hoc tests in Table 5 revealed that NaOH-treated fibers exhibited significantly higher compressive strength than CH_3COOH-treated fibers ($p<0.05$). While CH_3COOH-treated fibers had higher compressive strength than water-treated fibers, the difference was not statistically significant ($p>0.05$). Similarly, NaOH-treated fibers showed statistically significant differences compared to water-treated fibers under the LSD test ($p = 0.094$), but these differences were not significant with the Bonferroni correction.

Table 5

LSD and Bonferroni Multiple Comparison Results for 7-Day Compressive Strength

Comparison Group	Mean Difference (I-J)	Standard Error	LSD Significance	Bonferroni Significance	Lower CI	Upper CI
W vs A	-3.55000	3.16700	0.291	0.874	-10.7142	3.6142
W vs AK	5.92500	3.16700	0.094	0.283	-3.3648	15.2148
A vs A	9.47500	3.16700	0.015	0.045	2.3108	16.6392

The 7-day compressive strength results highlight the significant impact of fiber treatment methods on the mechanical performance of cement mortar. Water-treated fibers exhibit the lowest strength due to their hydrophilic nature, which weakens fiber-cement bonding and introduces voids, resulting in a consistent decline with increasing fiber concentration [10,17]. CH_3COOH-treated fibers show moderate performance, peaking at 36.5 MPa at 2% fiber concentration, as the removal of surface impurities like lignin and hemicellulose enhances fiber-matrix bonding [16,19]. However, uneven fiber dispersion at 5%-10% concentrations likely leads to clustering and strength reduction, while recovery at 15%-20% suggests a potential optimal range for this treatment [22]. NaOH-treated fibers deliver the highest compressive strength, averaging 32.3 MPa and peaking at 34.8 MPa at 0.5% concentration, due to alkali treatment's ability to remove non-cellulosic components, increase surface roughness, and reduce hydrophilicity, thereby improving interlocking and bonding [18,20]. Strength declines at higher concentrations (>10%) are attributed to reduced workability and void formation from fiber aggregation [20]. ANOVA results confirm the significant influence of treatment methods ($p = 0.043$), with NaOH-treated fibers significantly outperforming CH_3COOH-treated fibers ($p < 0.05$) [19]. These findings underscore the importance of fiber surface treatments and controlled concentrations in optimizing interfacial bonding and compressive strength [16,20,22].

3.2.3 28-day flexural strength

As illustrated in Fig. 9, the 28-day flexural strength of cement mortar without added straw fibers is 8 MPa. Incorporating water-treated and CH_3COOH-treated straw fibers results in a reduction in the 28-day flexural strength of the cement mortar specimens. However, the addition of NaOH-treated straw fibers at concentrations of 0.5% and 2% leads to an enhancement in the 28-day flexural strength, indicating a positive effect on the long-term performance of the specimens.

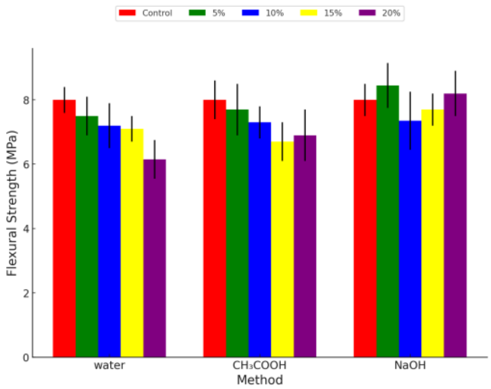

Fig. 9. 28-day Flexural strength of specimens with different treatment methods

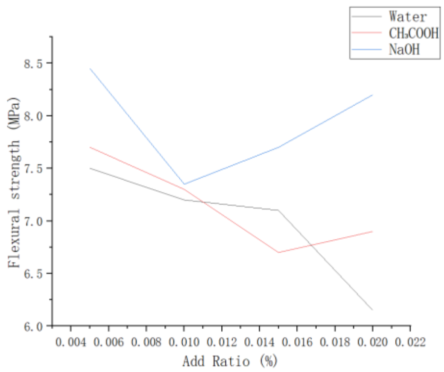

Fig. 10. 28-day strength curves for specimens with different treatment methods

Fig. 10 illustrates the distinct trends in flexural strength across varying concentrations of treated straw fibers. For water-treated fibers, the flexural strength consistently decreases with increasing fiber content, dropping from 7.5 MPa at 0.5% to 6.15 MPa at 2%. This suggests that higher fiber content may interfere with the bonding between fibers and the cement matrix, leading to a decline in performance. In contrast, CH_3COOH-treated fibers show a slight decline from 0.5% to 1.5%, followed by a modest rebound at 2%, indicating that the negative impact of CH_3COOH treatment on flexural strength is less pronounced compared to water treatment. NaOH-treated fibers exhibit a peak flexural strength of 8.45 MPa at 0.5%, followed by a decrease to 7.35 MPa at 1%, and a gradual recovery thereafter. This trend suggests that NaOH treatment initially enhances bonding strength but may cause some degradation at higher concentrations, after which the performance stabilizes.

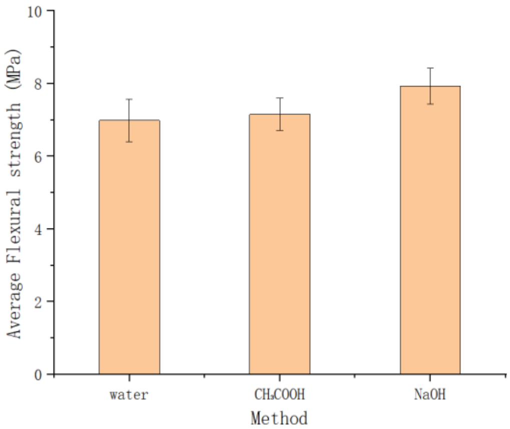

Fig. 11. 28-day average flexural strength for specimens with different treatment methods

Fig. 11 illustrates the 28-day average flexural strength for specimens with different treatment methods (Water, CH_3COOH, NaOH), excluding the control group. The average flexural strengths are as follows: water treatment achieves approximately 7.24 MPa, CH_3COOH treatment achieves approximately 7.15 MPa, and NaOH treatment achieves the highest average flexural strength at approximately 7.93 MPa. These results indicate that NaOH treatment is the most effective in improving the flexural strength of the cement mortar, potentially due to enhanced fiber-matrix adhesion and the strengthening of the mortar's internal structure. On the other hand, the water and CH_3COOH treatments provide similar results, with water treatment slightly outperforming CH_3COOH in terms of strength, likely due to the milder effect of water treatment on the fiber surface compared to CH_3COOH.

The ANOVA results in Table 6 indicate that the between-group sum of squares is less than the within-group sum, with an F-value of 3.854, which is lower than the critical value $F(2,9) = 4.26$. The p-value of 0.062 exceeds the significance threshold of 0.05, indicating no statistically significant differences among the treatment groups.

Table 6

ANOVA Results for 28-Day Flexural Strength

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p-value
Between Groups	2.008	2	1.004	3.854	0.062
Within Groups	2.344	9	0.260		
Total	4.352	11			

Despite the lack of statistical significance, the NaOH-treated group exhibited consistently higher flexural strength, suggesting its effectiveness in improving long-term performance. The variations in 28-day flexural strength stem from the chemical and physical effects of different straw fiber treatments on the fiber-cement matrix interaction. Water treatment, lacking chemical modification, results in poor interfacial bonding and increased void formation, leading to reduced strength as fiber concentration increases [21]. CH_3COOH treatment moderately improves performance by removing surface impurities like lignin and hemicellulose, exposing cellulose for better bonding, though its effectiveness is limited by uneven fiber surface modification [22]. In contrast, NaOH treatment achieves the highest flexural strength by removing non-cellulosic components, increasing surface roughness, and reducing fiber hydrophilicity, thereby enhancing mechanical interlocking and chemical bonding [18]. These findings align with studies emphasizing alkali treatment as one of the most effective methods for improving natural fiber-reinforced cement composites [23]. However, higher fiber concentrations (>10%) in NaOH-treated specimens lead to clustering and voids, offsetting the benefits. Optimizing treatment parameters and fiber content could further enhance performance [20].

3.2.4 28-day compressive strength

Fig. 12 illustrates the 28-day compressive strength of specimens treated with water, CH_3COOH, and NaOH at varying concentrations (0.5%, 1%, 1.5%, 2%), with trends further illustrated in Fig. 13. Water-treated specimens showed a slight decrease in strength from 46.1 MPa at 0.5% to 44.9 MPa at 2%, indicating a marginal reduction in strength as fiber content increases. CH_3COOH-treated specimens declined from 49.2 MPa at 0.5% to 45.3 MPa at 1.5%, then slightly recovered to 45.6 MPa at 2%. This suggests that while CH_3COOH treatment causes a reduction in compressive strength at lower concentrations, the strength stabilizes and shows a modest recovery at 2%. NaOH-treated specimens had the highest strength, peaking at 52.1 MPa at 0.5%, with minor fluctuations at higher concentrations. The consistent high strength across concentrations suggests that NaOH treatment effectively enhances the cement mortar's compressive strength, with 0.5% concentration showing the peak performance.

Fig. 14 shows the average 28-day compressive strength for each treatment type: water (45.53 MPa), CH_3COOH (47.05 MPa), and NaOH (49.65 MPa). Among these, water treatment had the lowest strength, indicating that water treatment alone does not significantly enhance the compressive strength of the mortar. CH_3COOH treatment showed moderate strength, slightly above water treatment, but did not reach the level of NaOH treatment. NaOH treatment achieved the highest strength, confirming its superior effectiveness in enhancing the long-term compressive strength of cement mortar specimens. NaOH treatment maintained high strength across concentrations, with peak performance observed at 0.5%. This indicates that NaOH treatment is highly effective in improving both the immediate and long-term mechanical properties of mortar, particularly in terms of compressive strength.

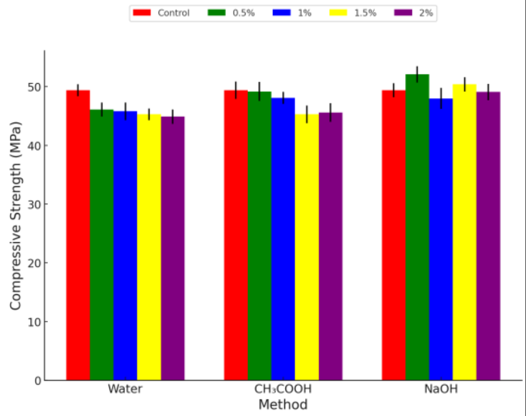

Fig. 12. 28-day Compressive strength of specimens with different treatment methods

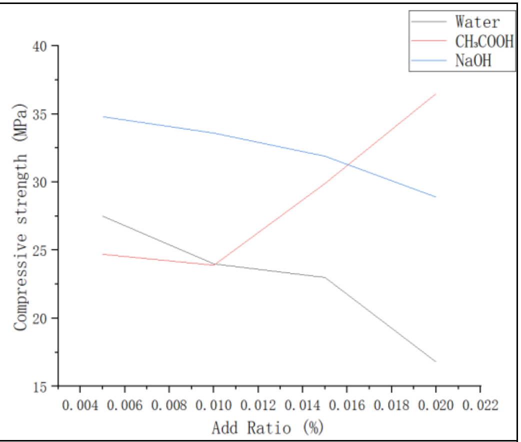

Fig. 13. 28-day compressive strength curves for specimens with different treatment methods

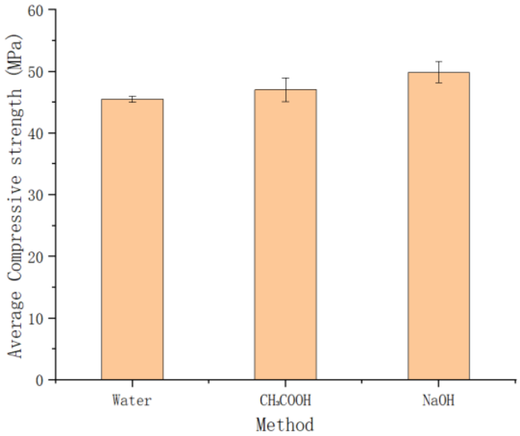

Fig. 14. 28-day average compressive strength for specimens with different treatment methods

The one-way ANOVA results in Table 7. The between-group sum of squares is greater than the within-group sum, with an F-value of 8.423, exceeding the critical value F(2,9) = 4.26. The p-value of 0.009 is less than 0.05, indicating a statistically significant difference among the treatment groups.

Table 7

ANOVA Results for 28-Day Compressive Strength

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	p-value
Between Groups	39.452	2	19.726	8.423	0.009
Within Groups	21.078	9	2.342		
Total	60.529	11			

The between-group sum of squares is greater than the within-group sum, with an F-value of 8.423, exceeding the critical value $F(2,9) = 4.26$. The p-value of 0.009 is less than 0.05, indicating a statistically significant difference among the treatment groups.

Post-hoc tests using LSD and Bonferroni methods were conducted to evaluate differences between treatment groups further. The results are summarized in Table 8.NaOH-treated fibers exhibited significantly higher compressive strength than both water- and CH_3COOH-treated fibers ($p<0.01$). The difference between CH_3COOH and water-treated fibers was not statistically significant ($p>0.05$).NaOH-treated fibers outperformed CH_3COOH-treated fibers, with LSD results showing a significant difference ($p=0.027$).

Table 8

LSD and Bonferroni Multiple Comparison Results for 28-Day Compressive Strength

Comparison Group	Mean Difference (I-J)	Standard Error	LSD Significance	Bonferroni Significance	Lower CI	Upper CI
W vs A	-1.52500	1.08211	0.192	0.577	-3.9729	0.9229
W vs AK	-4.37500	1.08211	0.003	0.009	-6.8229	-1.9271
A vs A	2.85000	1.08211	0.027	0.082	0.4021	5.2979

The 28-day compressive strength results reveal significant differences among the treatment methods, with NaOH-treated fibers achieving the highest strength, followed by CH_3COOH-treated and water-treated fibers. Water-treated fibers exhibited a consistent decline in strength with increasing concentration, primarily due to their hydrophilic nature, which weakened fiber-cement bonding and led to increased void formation in the matrix [17]. CH_3COOH treatment moderately improved compressive strength by removing lignin and hemicellulose, thereby enhancing fiber-matrix interaction. However, its effectiveness diminished at higher fiber concentrations (>10%) due to uneven dispersion, resulting in clustering and reduced strength. Interestingly, a slight recovery in strength was observed at 15%-20% concentrations, suggesting a potential optimal range for CH_3COOH treatment in achieving better uniformity and bonding [19,22]. NaOH-treated fibers demonstrated the highest overall performance, peaking at 52.1 MPa at 0.5% concentration. This is attributed to the removal of non-cellulosic components, which increased surface roughness, reduced hydrophilicity, and enhanced mechanical interlocking [18]. Nevertheless, higher fiber concentrations (>10%) led to workability issues and aggregation, offsetting the benefits of NaOH treatment and resulting in a decline in strength [20]. These findings underscore the effectiveness of NaOH treatment in enhancing compressive strength, while also highlighting the need to optimize fiber content and treatment parameters to minimize clustering and maximize performance [23].

4. Conclusions

This study demonstrates the significant impact of chemically treated corn straw fibers on the mechanical properties of cement mortar, highlighting their potential as sustainable reinforcement materials. CH_3COOH treatment significantly improved early-stage performance, achieving the highest 7-day flexural strength (average 6.475 MPa), primarily due to the effective removal of lignin and hemicellulose, which enhanced fiber-matrix bonding and reduced void formation. However, variability at higher concentrations (>10%) indicates challenges related to fiber dispersion, which require further optimization. In contrast, NaOH treatment exhibited superior long-term performance, achieving the highest 28-day flexural strength (7.93 MPa) and compressive strength (52.1 MPa). These results are attributed to its ability to improve fiber surface roughness, reduce hydrophilicity, and enhance interfacial bonding. Optimal fiber concentrations were identified between 0.5%-1.5%, as higher concentrations led to clustering and reduced performance for all treatment methods.

These findings emphasize the importance of balancing fiber content and surface treatment techniques to achieve optimal mechanical performance. Water treatment, while demonstrating the lowest performance, serves as a valuable baseline for understanding the significance of chemical modifications. Furthermore, CH_3COOH treatment is particularly effective in applications requiring enhanced early-stage performance, whereas NaOH treatment is better suited for long-term durability. Future research should explore hybrid treatment methods (e.g., combining acid and alkali processes) to integrate the benefits of both approaches, as well as advanced dispersion techniques to minimize clustering and ensure consistent reinforcement at higher concentrations. Additionally, comprehensive studies on the durability, environmental sustainability, and scalability of treated fibers are critical for their broader adoption in real-world construction applications. This study establishes a foundation for utilizing agricultural waste in high-performance, eco-friendly cement composites, advancing the development of sustainable construction materials.

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