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The effect of treatment way of wash water form ready-mixed concrete plant on the properties of mortar

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The settling time of wash water from a ready-mixed concrete plant in a tank will affect its solid content and ion concentrations, which will further influence the properties of new concrete mixed using that wash water. However, the effects of settling time and ion concentration have received scant attention. A method of simulating wash water formation in a ready-mixed concrete plant was provided in this article. Different settling times were designed, and a retarding component (RC) was added to change the solid content and ionic concentrations. The fluidity, strength, and hydration of mortar mixed with wash water were studied. The results show that a long wash water settling time can improve the strength of mortar, but the RC will increase the solid content and reduce the ion concentrations in the wash water. As a result, a longer settling time is required. In a word, a suitable wash water settling time is beneficial to mortar properties.

KEYWORDS
cement mortar, ion concentration, ready-mixed concrete, settling time, wash water

1 Introduction

In ready-mixed concrete plants, substantial amounts of wash water are generated daily from washing transport vehicles, mixers, and other supporting equipment. It is a highly alkaline waste that will pollute the soil and groundwater. As a result, "treatment system" and "utilization" of wash water from ready-mixed concrete plants are two main scoring items in the green production in Chinese JGJ/T 328–2014.

In the treatment of wash water from ready-mixed concrete plants, sand and stone were first separated, and then the pastes were multiply precipitated. After the treatment, the wash water contains not only some solid particles, such as hydrated cement particles, mineral admixture, fine sand, but also many hydration ions, such as Ca^{2+}, OH^{-}, SiO_4^{2-}, K^{+}, Na^{+}, and SO_4^{2-} (Wu et al., 2010). Yang et al. (2015) tested the concentration of ions in wash water from six ready-mixed concrete plants in five cities and found that the contents of Ca^{2+} and OH^{-} are relatively high. The Ca^{2+} and OH^{-} in wash water mainly come from the hydration of cement, while the K^{+} and Na^{+} are usually related to chemical additives, such as naphthalene-based plasticizer. SO_4^{2-} is mainly introduced by gypsum and chemical additives. At present, the washwater treated is mainly used as concrete mixing water.

The influence of wash water from ready-mixed concrete plants on concrete performance is a concern of many researchers. The effects of the addition amount and the solid content

of wash water have been studied. Rashad (2026) reviewed the literature from 1994 to 2025 and found that untreated concrete wash water typically reduces workability (5%–30% slump loss) and accelerates setting time due to its high pH and solid content; fixed-w/c designs exhibit strength reductions (5%–15%) from dilution effects (Rashad, 2026). Wash water will reduce workability (Abdi et al., 2024) but improve the compressive strength of concrete (Vaičiukynienė et al., 2021; Delnavaz et al., 2022; De Matos et al., 2020; Asadollahfardi et al., 2025). Concrete mixed with wash water can also obtain the equivalent strength of concrete mixed with tap water (Asadollahfardi et al., 2015; Su et al., 2002; Rong et al., 2007). Compressive strength, setting time, and drying shrinkage can also meet the requirements of BS EN 1008 (Low et al., 2007; BS EN 1008, 2002). However, wash water has a high alkaline content and a total solids content above the limit of ASTM C94, which may cause the concrete to be more porous and produce a weaker matrix (Cha et al., 2006; ASTM C94, 2007).

The ion concentration in wash water is also an important factor. Yang et al. (2015) tested ion concentrations in wash water and the strength of concrete mixed with wash water, but they did not further analyze the correlation between them. From their results, it can be found that all wash water has very low solid contents (<0.27%) but a large difference in ion concentration. This indicates that the difference in the strength should be related to the ion concentrations. Sandrolini and Franzoni (2001) also found that wash water with a high pH value reduces the slump of concrete. In addition, Rong et al. (2007) found that the setting time of mortar mixed with saturated lime water is prolonged, but the 3-day and 28-day strengths are increased. Their results may be related to the increase in the concentration of Ca^{2+} and OH^{-} in water.

Wash water is generally stored in a storage pool for some time before use. The wash water settling time has an important effect on the solid content and ion concentrations, which further affect the properties of concrete mixed with wash water. However, the effects of settling time are not clear, especially on ion concentrations, which limit the design of treatment programs and optimal utilization of wash water in concrete. Moreover, studying the effects of ion types and concentrations helps reveal the mechanisms of wash water in concrete. In this article, different settling times were designed, and a retarding component was added to change the solid content and ion concentration of wash water. Wash water was used as the mixing water of mortar, which has a similar mix proportion as a C30 concrete provided by a ready-mixed concrete plant. The effects of settling time on the fluidity, strength, and hydration of mortar were studied. The relationships between mortar properties and solid content and ion concentration were also analyzed.

2 Experiment

2.1 Preparation of wash water and test of solid content and ion concentration

Raw materials and mix proportion (Table 1) of C30 were provided by a ready-mixed concrete plant in Pingdingshan City. The slump of fresh concrete is 190 mm, and the 28-day strength is 36.5 MPa.

The concrete was divided into two equal parts. Some particles were removed with 2.36 mm sieves after some water was added to the mixed concrete. The solid content of concrete was adjusted to 8% by adding water again. The diluted concrete was placed in the sealed plastic buckets. The volume of the diluted concrete in every bucket was approximately 40 L. After it was placed for a time (6 h, 12 h, 24 h, 48 h, or 72 h), 500 mL of water was taken from the top of the paste in the bucket to prepare cement mortar. The water taken is called wash water in this article.

The pH value of the wash water was measured using a PHS-3E pH meter. Ion concentrations were tested using a PerkinElmer Optima 7000DV Inductively Coupled Plasma Optical Emission Spectrometer. Before the ion concentration tests, the water taken was filtered using a 0.45 μm filtration membrane and then neutralized with nitric acid.

The solid content of wash water was obtained by measuring the mass before and after it was dried at 105 °C. The mass of wash water was 100 g.

2.2 Preparation of mortar with wash water and property testing

2.2.1 Raw materials

A 42.5 MPa silicate cement and II-grade fly ash were used. The chemical composition and physical properties are shown in Tables 2, 3, respectively. A II-zone river sand was used, which has a fineness modulus of 2.4, an apparent density of 2.61 × 10^3 kg/m^3, and 1.5% soil content. A polycarboxylate plasticizer was used to adjust the workability of the cement mortar or concrete. Its solid content was 10%, and the water-reducing rate was 25%. A retarding naphthalene-based plasticizer (RC) was used to adjust the wash water properties. Its solid content was 10%, and the water-reducing rate was 20%. The water used in the mix is the wash water mentioned above, after different settling times.

2.2.2 Testing methods of mortar properties

Mortar has a similar mix proportion to the above C30 concrete, as shown in Table 4.

The fluidity of fresh mortar was tested according to Chinese standard GB/T 2419–2005.

The mortar strength test was conducted according to Chinese standard GB/T 17671–2021. The size of the sample was 40 mm × 40 mm × 160 mm. After molding, the samples were cured in 20 °C water. The 3 d and 28 d strengths were tested.

The hydration of mortar was analyzed by the bound water content in a 2 cm × 2 cm × 2 cm sample of the hardened paste. After curing, the hardened paste was crushed into small particles. Then, the particles were placed in anhydrous ethanol for 2 weeks to terminate hydration. Finally, the particles were ground to pass through a 45-μm sieve. The bound water content in the hardened paste was analyzed by NETZSCH STA 449 F3 analysis. The heating rate was 10 °C/min, and the final temperature was 1,000 °C.

TABLE 1 Mixing ratio of C30.

-	Cement	Sand	Stone	Fly ash	Plasticizer	Tap water
Type	P.O 42.5	Medium	5–20 mm	II	FDN-G	-
Amount (kg/m^3)	280	854	1,010	90	6.8	170

TABLE 2 Chemical composition of the cement and fly ash.

Materials	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	Na_2O	K_2O
Cement	61.93	18.88	5.91	2.78	3.88	4.55	0.23	1.14
Fly ash	4.94	53.00	31.30	4.65	0.73	0.76	0.33	2.63

TABLE 3 Physical properties of the cement and fly ash.

Materials	Initial setting	Final setting	28 d strength	Fineness (45 μm)	Water demand	Activity index
Cement	155 min	258 min	47.8 MPa	8%	-	-
Fly ash	-	-	-	15%	98%	71%

TABLE 4 Mixing ratio of mortar.

-	Cement	Fly ash	Sand	Plasticizer	Wash water
Amount (g)	280	90	854	4.44	170

3 Effect of the wash water on the properties of cement mortar

3.1 Fluidity of mortar

The effect of the wash water settling time on the fluidity of fresh mortars is shown in Figure 1, and 0 h represents the reference sample mixed with tap water. The fluidity is greatest at 12 h of settling time and is higher than that of the sample with tap water at all settling times of less than 24 h. However, it is almost the same as that of the sample with tap water when the settling time is more than 24 h. When RC is added to the wash water, the fluidity is clearly different from that of the sample without RC.

The effect of wash water on the fluidity of cement mortar may be related to the addition of RC to concrete or wash water. The effect of RC continues to play a role in cement mortar when the settling time is shorter.

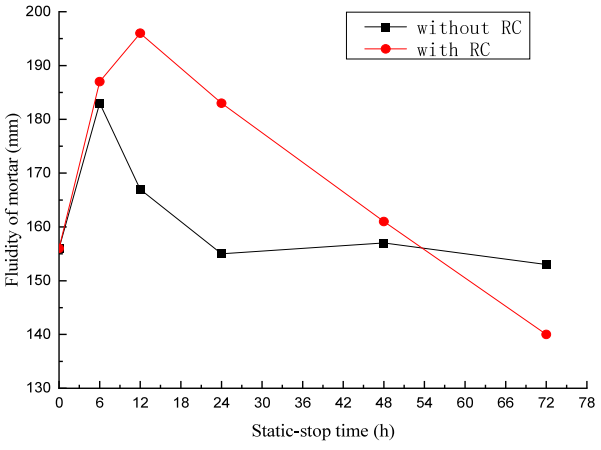

FIGURE 1
Fluidity of fresh mortar at different settling times.

3.2 Compressive strength of mortar

The compressive strengths of the hardened paste made with wash water at the different settling times are shown in Figure 2.

At 3 days, the sample made with wash water without RC has an increased 3-day strength compared to the sample made with tap water, and the strength is highest at the settling time of 12 h. However, when RC is added to the wash water, the settling time has a great effect on the strength. The strength is rapidly increased at settling times of less than 24 h and then continues to increase. The strength is lower than that of the sample with added wash water without RC at the same settling time, and even at settling times of less than 24 h, the strength is less than that of the sample mixed with tap water.

The 28-day strength of the sample with added wash water is almost similar to its 3-day strength with the same settling time. At the settling time of 72 h, the wash water with RC

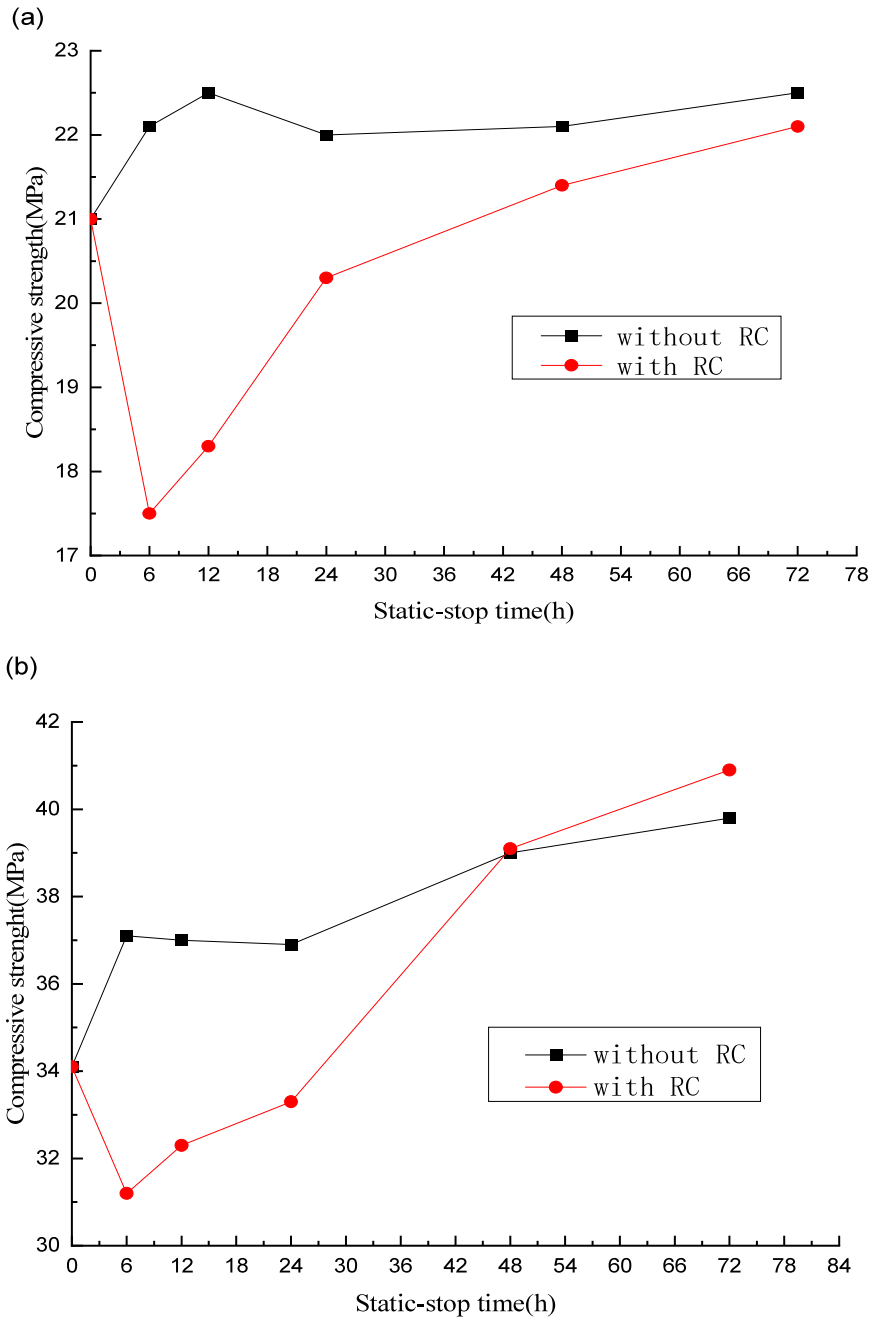

FIGURE 2
Compressive strength of mortar at different settling times: **(a)** 3 days and **(b)** 28 days.

increases the strength compared with the wash water without RC. This indicates that there is an effective settling time for the wash water at which the strength of the concrete is rapidly increased.

The above difference shows that the properties of wash water have an important effect on the strength, especially with the addition of RC. In addition, RC may directly affect the hydration of cement when the settling time is shorter. The properties of wash water will be analyzed in Section 4.

3.3 Hydration of hardened paste

Tables 5, 6 show the contents of $Ca(OH)_2$ and non-evaporative water in the hardened paste with added wash water with or without RC. The content of $Ca(OH)_2$ and non-evaporation water increases with settling time and curing age. The wash water with RC reduces the content of CH and non-evaporation water.

Compared with tap water, the wash water without RC increases the content of CH and non-evaporation water, but the wash water

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TABLE 5 $Ca(OH)_2$ content in hardened paste (wt%).

Ages	6 h-RC	6 h	48 h-RC	48 h	72 h-RC	72 h	Tap water
3 d	7.98	9.70	7.52	8.51	10.85	8.26	7.85
7 d	8.92	7.81	9.13	10.32	10.57	9.17	9.41
28 d	9.25	11.14	9.91	10.48	11.22	12.25	11.06

TABLE 6 Non-evaporation water content in hardened paste (wt%).

Ages	6 h-RC	6 h	48 h-RC	48 h	72 h-RC	72 h	Tap water
3 d	9.16	9.2	9.91	10.74	10.00	9.83	11.09
7 d	9.82	11.28	10.91	11.95	11.38	11.82	11.68
28 d	12.91	12.88	12.82	13.67	13.38	13.83	11.97

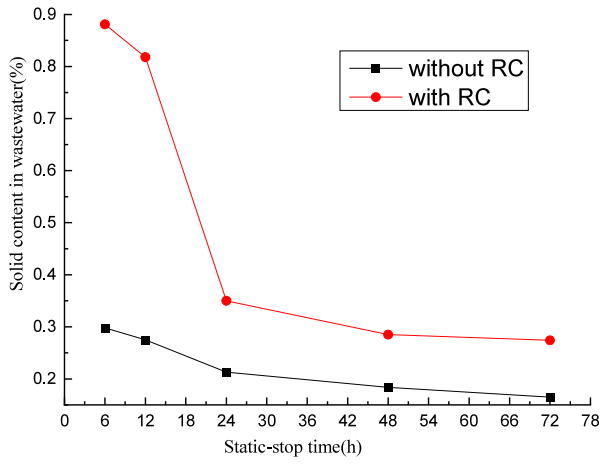

FIGURE 3
Solid content in wash water at different settling times.

FIGURE 4
Color of wash water without RC through a 0.45 μm filtration membrane at different settling times.

with RC has a negligible effect on the content of CH and non-evaporation at 3 days and 7 days. This indicates that wash water promotes the hydration of cement, and adding RC to the wash water can have an active effect only at longer hardened ages.

FIGURE 5
Color of wash water with RC through a 0.45 μm filtration membrane at different settling times.

4 Discussion

The wash water contains some solid particles and hydrated ions. The increase in solid content decreases the strength of cement, while the hydrated ions affect the hydration of cement.

4.1 Solid content in wash water

The change of solid content in the wash water with settling time is shown in Figure 3. The solid content is below 0.30% in wash water without RC. It is also reduced with the settling time, especially before 24 h, and is only 0.16% at 72 h. However, RC obviously increases the initial solid content (0.88%). The solid content is rapidly reduced before 24 h but is still higher than that in the wash water without RC at 72 h (0.27%).

The increase in the initial solid content is related to the adsorption and dispersion of RC to cement particles. The retarding component adsorbs to the surface of the solid particles, suspending them in the water. As a result, the settlement rate of the particles is reduced, and the solid content is increased in the wash water. The

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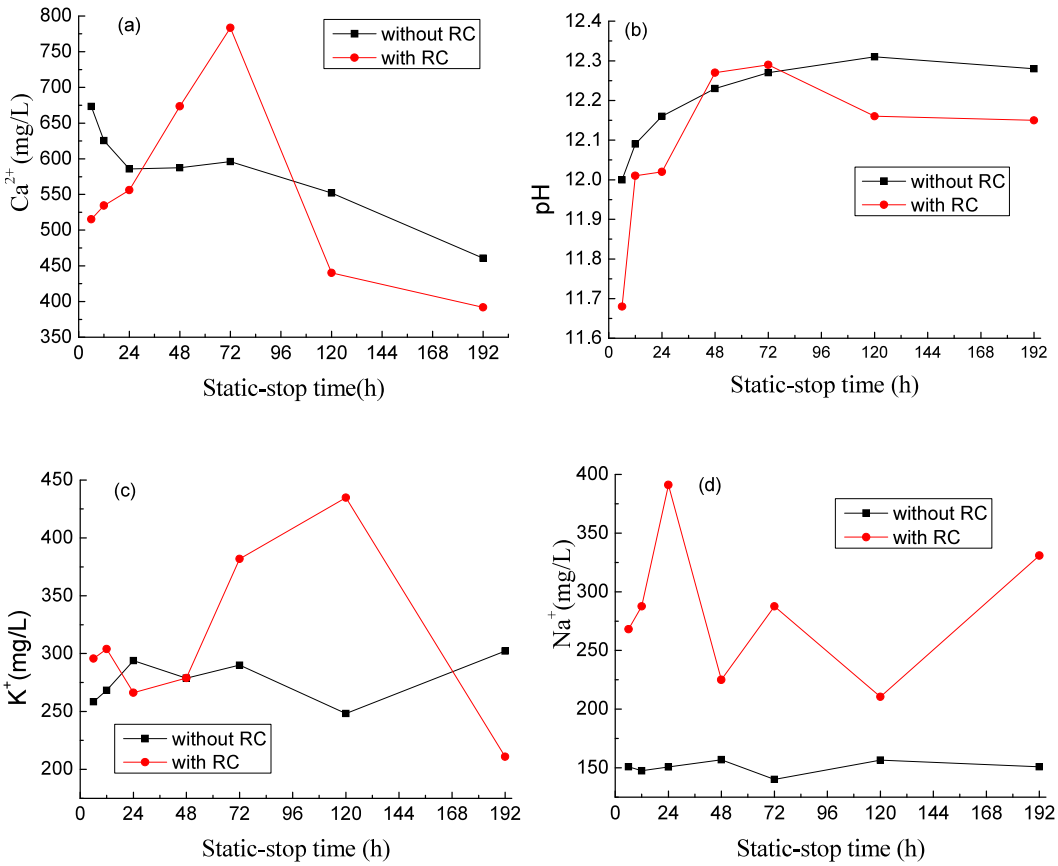

FIGURE 6
Ion concentration in wash water at different settling times: **(a)** Ca^{2+}, **(b)** pH value, **(c)** K^+, and **(d)** Na^+.

decrease in solid content with settling time is related to the reduction in the effect of RC.

At the same time, it can be observed from Figures 2, 3 that even after multiple filtrations using a 0.45 μm filtration membrane, the content of solid particles is still relatively high so that the wash water containing retarding components is darker.

Even after filtration through a 0.45 μm filtration membrane, the solid content was still relatively high in the wash water containing RC, which was yellow (Figures 4, 5). The color gradually changes from dark yellow to light yellow with increasing settling time.

4.2 Concentration of ions in the wash water

The concentrations of Ca^{2+}, K^+, Na^+, and OH^- in the wash water at different static times are shown in Figure 6.

The concentration of Ca^{2+} in the wash water without RC is gradually decreased with increasing settling time, and the change is relatively obvious before 24 h. RC added reduces the initial concentration of Ca^{2+}, but its concentration is rapidly increased with settling time before 72 h and then begins to decrease. Its concentration is significantly higher than that without RC during the time from 48 h to 100 h (Figure 6a). The pH value changes differently compared with that of Ca^{2+}. The pH increased with the settling time in the wash water without RC, while it had a similar change to Ca^{2+} in the wash water with RC (Figure 6b). The reason is that Ca^{2+} is not only involved in the formation of $Ca(OH)_2$ but also involved in the formation of other products, such as C-S-H. In addition, the rapid decrease in the contents of Ca^{2+} and OH^- during the 72 h–120 h period indicates the rapid formation of $Ca(OH)_2$ in the wash water with RC, which corresponds to the change in $Ca(OH)_2$ content shown in Tables 4, 5.

The difference in Ca^{2+} content in wash water with and without RC shows that RC influences the hydration of cement: RC delays the hydration of cement in a short settling time, but the retarding effect is gradually lost, and the hydration is accelerated with prolonged settling times.

The content of K^+ and Na^+ is also different in the wash water with and without RC (Figures 6c,d). The similar changes of K^+ and Ca^{2+} show that they are related to the dissolution of K^+ in cement. The relatively stable concentration of Na^+ in the wash water with RC indicates that its source is mainly from the naphthalene-based plasticizer.

4.3 Relationship between the properties of wash water and the strength of cement

Cement particles in the wash water are hydrated, and therefore, the concentrations of ions in the wash water are higher than those in tap water. When the wash water is added to the cement, the initial concentrations of ions in the paste are higher, which accelerates the formation of hydration products and improves the degree of hydration (as shown in Tables 2, 3). Rong et al. (2007) found that the 28-day strength of mortar mixed with saturated lime water increased. Çomak (2016) found that alkaline mixing waters (up to pH 13) have positive effects on the compressive strength and workability of the cement mortars. At the same time, the solid particles in the wash water can act as micro-aggregates, which fill the pores of concrete and improve the density (Li, 2015). The solid particles can also be used as heterogeneous nucleating agents to accelerate the nucleation and crystallization of hydration products. Yang et al. (2015) found that the wash water with a solid content of 0.27% significantly increases the 28 d strength. Other researchers also found that the strength of cement or concrete increased when the solid content in wash water was lower (He et al., 2011; Li, 2009; Zeng et al., 2009). In this study, the solid content of the wash water without RC was lower than 0.3% and further decreased with the settling time. The lower solid content and higher ion concentration of the wash water favor the development of cement strength (Figure 4).

As the solid content in the wash water increases, the ion concentrations also increase. Two pastes with water-to-cement ratios of 5:1 and 10:1 were prepared to observe the change in ion concentration. At the same time, the concentrations of Ca^{2+} were almost the same. A thin sheet of $Ca(OH)_2$ formed on the surface of pastes, suggesting that the concentration of Ca^{2+} was saturated. This suggests that once the solid content is above a certain value, the change in ion concentration will be very small. Li (2009) found that the cement strength was virtually unchanged when the solid content of the wash water increased to 3%. At the same time, the increase in solid content in the wash water is equivalent to reducing the content of cement within a unit of paste. Ma and Wang (2013) found that when the replacement of waste concrete fine powder is higher than 10%, cement strength decreased. In addition, the double-electron layer structure formed on the surface of the particles will bind some water, which reduces the content of free water in the paste. As a result, the strength will be reduced. Geng et al. (2015) found that the strength is significantly decreased when the solid content exceeds 5%.

RC reduces the hydration degree of cement particles and the concentration of Ca^{2+} but increases the solid content in the wash water. The hydration and strength of cement are reduced. As the settling time is prolonged, the solid content is reduced in the wash water, but the concentration of Ca^{2+} is increased due to the hydration of cement particles. The hydration degree of cement and strength is also gradually increased (Table 2 and Figure 4). In addition, RC in the wash water continues to play a retarding role in cement paste and affects the strength development.

In general, the wash water can improve the hydration and strength of cement, while RC extends the wash water settling time and reduces the hydration and strength. Due to a limited amount of wash water available to a mixing plant every day, extending the settling time can improve the storage of the wash water, and it can also make the use of the wash water more favorable for a ready-mixed concrete plant.

5 Conclusion

A study of the settling time of wash water from a ready-mixed concrete plant was designed. The effect of settling time on solid content and ion concentration of wash water was studied. The fluidity and strength of mortar mixed with wash water after different settling times were analyzed. The conclusions are as follows.

1. The use of wash water promotes the hydration of cement and improves the strength; adding a retarding component to the wash water may reduce the effect of the wash water.
2. The settling time will affect the concentration of ions in the wash water. An appropriate settling time ensures that the wash water will maintain a high concentration of ions, which can promote the hydration of cement.
3. A retarding component increases the solid content in the wash water. If a longer settling time is provided, the effect of solid content will be weakened, and the strength of the mortar will be improved.

In a word, a suitable settling of wash water is beneficial to the properties of mortar, and a retarding agent can leave a longer optimal settling time. Many factors must be considered, such as the amount of water added to concrete, concrete compositions, and the environmental conditions of wash water storage. The factors also affect the solid content and ion types and concentrations in wash water. The environmental conditions of stored wash water should be further studied because they can change the hydration of cement particles in wash water.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

HZ: Conceptualization, Writing – original draft. XM: Investigation, Writing – original draft. XW: Data curation, Formal Analysis, Conceptualization, Funding acquisition, Writing – review and editing. FZ: Supervision, Writing – original draft. LY: Validation, Visualization, Writing – original draft.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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