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Research Article

Influence of casting delay on concrete compressive strength

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ABSTRACT

This research aims to evaluate the effect of evaporation and casting delay (delaying in pouring concrete after mixing, up to 120 minutes) on the concrete compressive strength (CCS) after 7, 14, and 28 days. To examine this, Portland Composite Cement (PCC) and Ordinary Portland Cement (OPC) were utilized with water-cement (w/c) ratios of 0.5 and 0.6. The CCS was assessed for four distinct casting delay durations (0, 30, 60, and 120 minutes) and for two conditions: with and without evaporation. A total of 288 cylinders (4”×8”) were made, and a CCS test was conducted. The test findings showed that, for a w/c of 0.6, using a casting delay of 120 minutes increased the CCS of specimens made with OPC cement by about 23%, 22.5%, and 2% at 28, 14, and 7 days, respectively, when evaporation was allowed. However, with a w/c of 0.5, it increased 28%, 42%, and 21% at 28, 14, and 7 days, respectively. The strength test results revealed increases of 18.9%, 36%, and 17.8% for 0.5 w/c when evaporation was prohibited. Specimens made with PCC (w/c of 0.5 and 0.6) showed opposite results, with strength decreasing with casting delay for both evaporation and non-evaporation conditions. At 0.6 w/c, the strength decreased by 6.4%, 6.2%, and 28.3% at 28, 14, and 7 days when evaporation was allowed, and the strength decreased by 5%, 2%, and 11.3% at 28, 14, and 7 days when evaporation was not allowed. Compared to OPC, the PCC exhibits a very slight increase in strength.

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1. Introduction

Concrete is a basic composite material that includes aggregates (sand, gravel, or crushed stone) and cement paste (Gagg 2014). Concrete is one of the most widely used construction materials because it is readily available, inexpensive, easily cast into any shape, and has favorable handling characteristics (Hasan and Kabir 2011; Roknuzzaman et al. 2024, 2025). The behavior of a structure made with reinforced concrete is affected by numerous parameters, such as the quality of the concrete, reinforcements, and workmanship. The concrete compressive strength (CCS) is an important parameter to measure its performance. The non-homogeneous characteristic of the concrete renders it vulnerable to performance problems that may be a result of inappropriate design or defective mix proportioning of its materials (Nasir et al. 2020; Roknuzzaman and Rahman 2024). Besides, the CCS depends on various factors such as concrete age, period of curing, curing temperature, and the amount of superplasticizer applied; incubation time before curing and water rate in the mix are also among these factors (Hardjito et al. 2004; Esparham and Moradikhou 2021). The casting delay time can be another such factor affecting the CCS (Sapkota and Mishra 2024), which is thereafter called the time lag between the finishing of concrete mixing and pouring for the making of cylinders.

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In the computation of the CCS by compression test on a concrete cube or cylinder, the water-cement (w/c) ratio is believed to be the most important parameter that influences concrete strength (Ayanlere et al. 2023). For instance, Shamsai et al. (2012) obtained an enhancement in CCS by 34.4–35.2% with the decrease of w/c from 0.5 to 0.33. In the same way, through an aggregate replacement of burnt brick in concrete production and by decreasing the value of the w/c ratio from 0.5 to 0.4, it was found that CCS increased more than 30% (Kumar et al. 2023). On the other hand, for quarry dust concrete, compressive strength and split tensile strength were reduced as the w/c ratio increased from 0.5 to 0.65 (Rao and Sen 2017). Gavela et al. (2018) also reported that the use of limestone as a coarse aggregate with superplasticizer and reduction of the w/c ratio from 0.54 to 0.46 enhanced CCS from 69 to 80 MPa. In addition to the w/c ratio, other factors significantly affect concrete performance. Contaminated mix water, which is often contributed by sewage or swamps and contains sulfate ions, could potentially reduce CCS of concrete as well as retard initial and final setting times for OPC and PPC (N'Simba et al. 2023). Moreover, the longer curing time will result in a higher degree of hydration and thus better performance of concrete at compressive strength (Roknuzzaman et al. 2025). Additives such as superplasticizers and retarders possessing excellent compatibilities can help improve the workability of concrete and avoid segregation, but if in greater quantities, they will have an adverse effect (Barbhuiya et al. 2025). In fact, it can be seen that the cement composites with superplasticizers, retarders, and fly ash also significantly contributed to enhancing both the CCS and flexural strength of the concrete (Singh et al. 2015). The process of re-tempering has also been studied for its effects. Abdel-Aziz et al. (2019) investigated the effect of water as a re-tempering agent on the compressive and tensile strength of concrete. They found that 10% water added after a delay of 45 min restored the original slump value, however. They found that re-tempering for 1 hour or longer made the steel harder, but that re-tempering for 0 to 120 minutes weakened it in both compressive and tensile strength. Similarly, the effect of superplasticizer dosage and time delay (up to 90 minutes) on the slump value and CCS of self-compacting concrete was studied by Zeyad and Almalki (2020). They also found that the maximum value of CCS was obtained with a 15 min delay and then started to decrease. Furthermore, the slump flow decreased by 6%, 19%, and 27% with increasing mixing times of 30, 60, and 90 minutes, compared to the slump flow observed at a mixing time of only 15 minutes.

Unlike some results, Chy. et al. (2016) showed that the cast delay did not reduce but enhanced the CCS for different OPC w/c ratios. But in the case of ready-mixed concrete firms, Sobhani et al. (2012) identified that delays in casting lead to a high reduction of workability and effectively may make the concrete unworkable. Too long of a pour delay will result in unfit concrete being placed. Other studies have reported inconsistent findings on this issue. Rathi and Kolase (2013) stated that in the absence of a retarder, the late placing of the second part caused an increase in the strength of a concrete sample. More precisely, the CCS was higher for delay times up to initial setting time and lower for delay times beyond initial setting time. Likewise, Mohamadien (2013) investigated the influence of the cold joints for a second layer of concrete with delay times of 4, 9, and 16 h. It was concluded that the CCS reduced with an increase in the casting times at which the second layer was cast. Contradictorily, the CCS was reduced by 3%, 4%, and 7% at ages of 4, 9, and 16 h as a result of the grouting between two layers. Mahzuz et al. (2020) analyzed the effects of casting delay on the 28-day compressive strength for PLC and OPC. Their results showed that replacing the water lost every hour to maintain workability led to a decrease in CCS of cylinders over time, whereas adding no water after a resting period resulted in rapid loss of workability and strength.

On the worksite, concrete cannot be placed just-in-time because of the transit time to the site, site logistics, workforce availability, etc. This may delay the pouring of concrete, meaning that the mixture loses workability. This situation may injure the concrete's mechanical characteristics. For example, Mahzuz et al. (2020) indicated that adding water to recover the workability decreased the CCS. Despite the above-mentioned studies, the combined influence of evaporation and delayed casting time on CCS has received limited attention in the research area. Therefore, the purpose of this study was to examine the effect of placement delay and moisture loss on compressive strength of freshly mixed concrete made with OPC and PCC using two different w/c ratios of 0.5 and 0.6.

2. Materials and Methods

The materials characteristic's (binder, sand, and coarse aggregate), the sample preparation, and the testing procedure are discussed in this section.

2.1. Material properties

Two types of cement were utilized as binding agents in this investigation. OPC is made of 95-100% clinker, 0% limestone, and 0-5% gypsum (ASTM C150/C150M 2024), while PCC is composed of 72-79% clinker, 21-28% blast furnace slag and limestone, and 0-5% gypsum (BDS EN 197-1 2010; ASTM C595/C595M 2012). According to ASTM C191 (2021), the VICAT Apparatus is used to estimate the setting time of cements. Following ASTM C187 (2023), the typical consistency of OPC and PCC was evaluated. As a fine aggregate, Sylhet sand was used, which was locally available and widely used fine aggregate in the construction field of Bangladesh. Sieve analysis was conducted for the sand in compliance with ASTM C136 (2019) to determine the fineness modulus. Bulk density, specific gravity, and water absorption of sand were determined in accordance with ASTM C29/C29M (2023) and ASTM C128 (2025). In this study, crushed stone up to ¾ inch in dimension was used as a coarse aggregate. Table 1 depicts the properties of coarse and fine aggregate.

Bulk specific gravity and absorption were assessed following ASTM C127 (1992). The standard consistency, and setting time of both OPC and PCC are listed in Table 2 (throughout the paper, hr. refers to hour and min. refers to minutes).

Table 1. Characteristics of course and fine aggregate.

Properties	Sand	Stone-chips
Bulk specific gravity	2.52	2.61
Absorption	1.94 %	1.2%
Unit weight	1525 kg/m^3	1518 kg/m^3
Fineness modulus	2.6	–

Table 2. Setting times and consistency of cement.

Type of cement	Consistency	Initial setting time	Final setting time
OPC	25%	1 hr. 55 min.	4 hr. 40 min.
PCC	27%	2 hr. 20 min.	5 hr. 25 min.

2.2. Sample preparation

This study aims to determine how the casting delay time (delaying in casting after mixing concrete) affects the concrete compressive strength built using locally available PCC and OPC. For the study purpose, the placement time has been altered for two circumstances, leaving the other attributes of the concrete component (coarse aggregate, fine aggregate) unchanged. One condition permits evaporation exposing concrete mixture in air before pouring into molds, whereas the other does not allow evaporation and this was ensured by covering concrete mixture by a plastic sheet before pouring into molds. For two distinct w/c ratios (0.5 and 0.6), PCC and OPC are used in various ways when producing concrete. For both w/c ratios, the amounts of cement and concrete constituents had been computed. Table 3 lists the necessary quantity of concrete materials for casting concrete based on the ACI mix design procedure (ACI 211.1 1991).

Table 3. Quantity of concrete ingredients.

w/c ratio	Cement (ft^3)	Water (lb)	Sand (ft^3)	Stone-chips (ft^3)
0.5	1.4	44	2.1	4.2
0.6	1.4	53	2.1	4.2

ASTM C470/C470M (2023) standard was followed to create the standard concrete specimen molds. The mold utilized in this study is cylindrical in form, measuring 4” in diameter by 8” in height. Before any concrete was poured, each mold was carefully cleaned, dried, and an oil layer was applied to prevent the concrete from sticking to the mold. The mixing proportion of cement, sand and stone-chips was 1: 1.5: 3 for both w/c ratios (0.5 and 0.6). The mixing of the concrete elements was completed using a concrete mixer. The goal of the mixing process, which basically consists of rotating or stirring, was to integrate all the concrete elements into a homogenous mass and apply cement paste to the surface of every aggregate particle. The concrete was filled into the cylinder and was compacted using a standard vibrator. The process of compaction and specimen preparation is shown in Fig. 1. We generated four distinct concrete specimens by exposing the concrete to air for evaporation (evaporation allowed), corresponding to delay durations of 0, 30, 60, and 120 minutes. The concrete mix was kept in rest during these casting delay time. There was a little slump loss but it was within the standard limit as prescribed by ACI. The casting was conducted during winter, and the atmospheric temperature was almost unchangeable during the casting delay period.

Fig. 1. Specimen preparation and vibration.

A total of 288 concrete specimens were made under this situation, accounting for two distinct water-to-cement ratios. Concrete was encased in thick plastic to inhibit evaporation (evaporation not allowed), and four more types of concrete specimens were created, considering four specific delay intervals: 0, 30, 60, and 120 minutes.

Before the molds were taken out, the concrete samples were kept in air for about a day, and then the specimens were soaked in water for curing of prepared cylinders. For four distinct casting delay times (shown in Table 4), the cylinders were prepared with and without permitting evaporation. Table 4 displays general information about specimen preparation and testing.

Table 4. Details of specimen preparation and testing.

General information on specimen preparation and testing	
Cement type	OPC and PCC
w/c ratios	0.5 and 0.6
Curing type	Continuous curing up to the breaking of specimens
Casting delays considered	0, 30, 60, 120 min.
Test repeated for a particular group	3
Period of concrete testing	7, 14, 28-days

2.3. Testing

After being removed from soaking storage, a compressive strength test of the moist-cured specimens was conducted. Before testing, the ends of the specimens were smoothed with a grinder so that the load became uniform over the surface. The concrete specimens were tested after 7, 14, and 28-days in a CCS test machine to evaluate concrete strength. The tests were conducted following ASTM C39/C39M (2014). Fig. 2 displays the testing of a concrete specimen.

The CCS of a specimen is determined by dividing the highest load by its average x-sectional area. The concrete specimens were subjected to a load till it failed. Eq. (1) was used to assess the CCS of the specimens.

$$F_m = \frac{P}{A} \tag{1}$$

where, F_m = CCS of specimen (psi); P = highest load recorded from the test (lb); A = average x-sectional area of specimen (in^2).

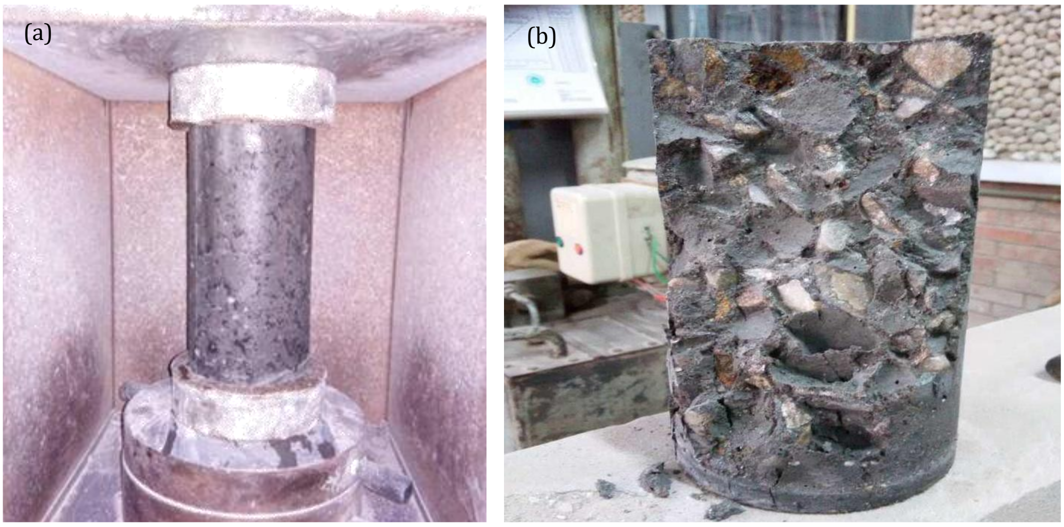

Fig. 2. Concrete specimen testing: (a) During test; (b) After failure.

3. Results and Discussion

The summary of the test results is provided in the following subsections.

3.1. Effect of casting delay allowing evaporation

Figs. 3 to 6 present the outcomes of CCS tests conducted using two distinct cement types: OPC and PCC, with water-to-cement ratios of 0.5 and 0.6. Four different casting delay times were considered, and evaporation was permitted. Overall, it is clear that OPC with a water-to-cement ratio of 0.5 obtained the highest CCS (Fig. 3), while PCC with a water-to-cement ratio of 0.6 achieved the lowest compressive strength (Fig. 6). The concrete compressive strength increased by around 28%, 42%, and 21% at 28, 14, and 7-days, respectively, for OPC with a w/c ratio of 0.5 (Fig. 3) when the casting delay time was 120 minutes, as opposed to zero minutes of casting delay. However, for the same cement with a w/c ratio of 0.6 (Fig. 4), this increase in CCS is around 23%, 22.5%, and 2% at 28, 14, and 7-days, respectively. For OPC, the CCS generally increases as the casting delay time increases for both water-to-cement ratios.

PCC has an adverse effect on strength gain with casting delay time. Compressive strength in PCC decreases as casting delay time increases for a w/c ratio of 0.6 (Fig. 6) and this happened at 120 minutes casting delay. The decrease in CCS is around 28.3%, 6.2%, and 6.4% at 7, 14, and 28-days, respectively, with 120 minutes casting delay compared to zero minutes casting delay. The possible reason is that the delay time is close to the initial setting time which cause loss of plasticity (loss of monolithic behavior) and microcrack formation (Neville 2011). At a 0.5 w/c, the compressive strength of concrete gradually increases with the increase of casting delay (Fig. 5). The reason behind this strength increase with casting delay was pre-hydration densification (Neville 2011). Due to the moderate delay in casting, the concrete paste became more cohesive (formation of Calcium Silicate Hydrate, C-S-H), the bleeding was reduced, refined the interfacial transition zone (ITZ), resulting in lower capillary porosity and higher compressive strength (Neville 2011). In conclusion, the CCS composed of PCC with a w/c equal to 0.6 negatively impacted by casting delay time; however, for OPC, the concrete compressive strength rose noticeably with casting delay.

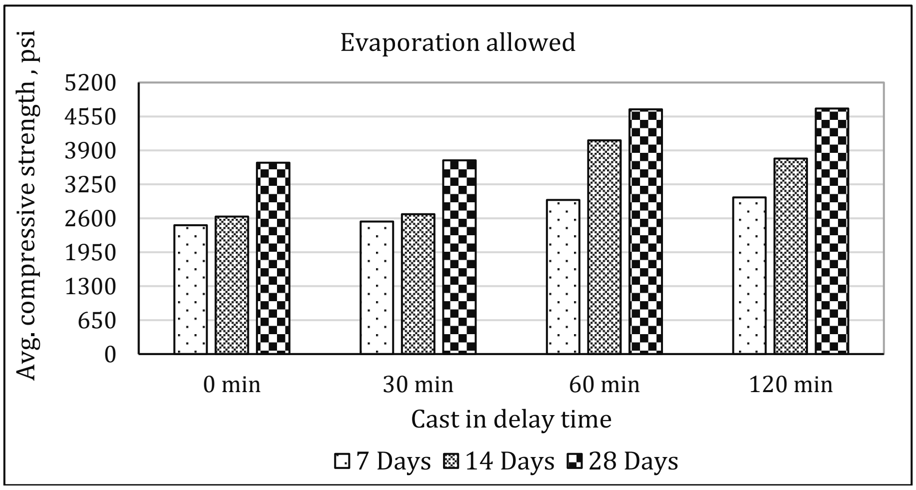

Fig. 3. Variation of CCS with casting delay (OPC, w/c =0.5).

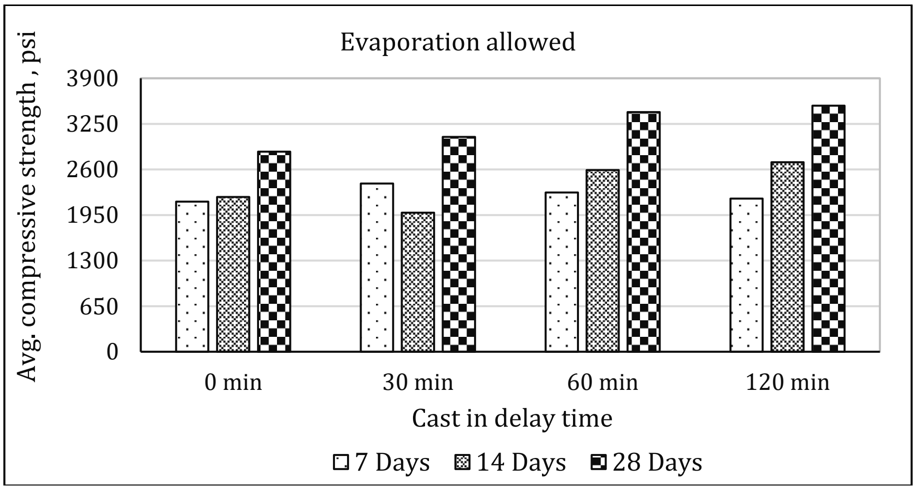

Fig. 4. Variation of CCS with casting delay (OPC, w/c =0.6).

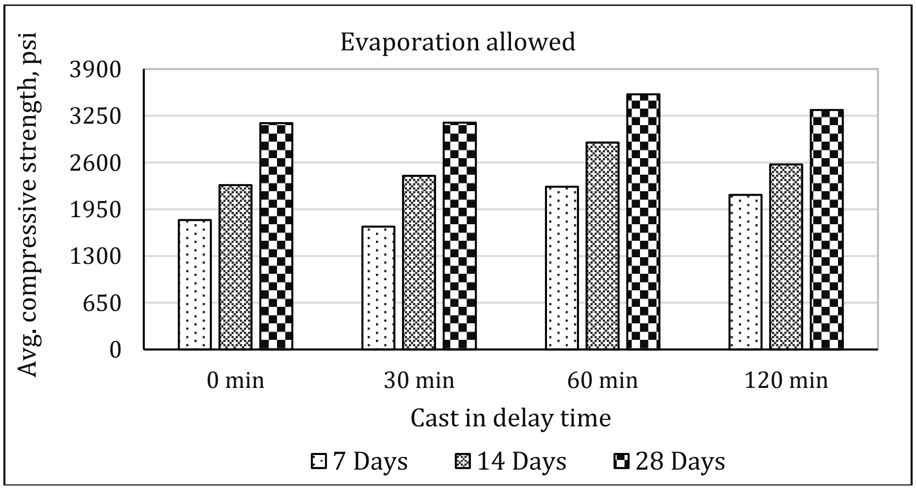

Fig. 5. Variation of CCS with casting delay (PCC, w/c =0.5).

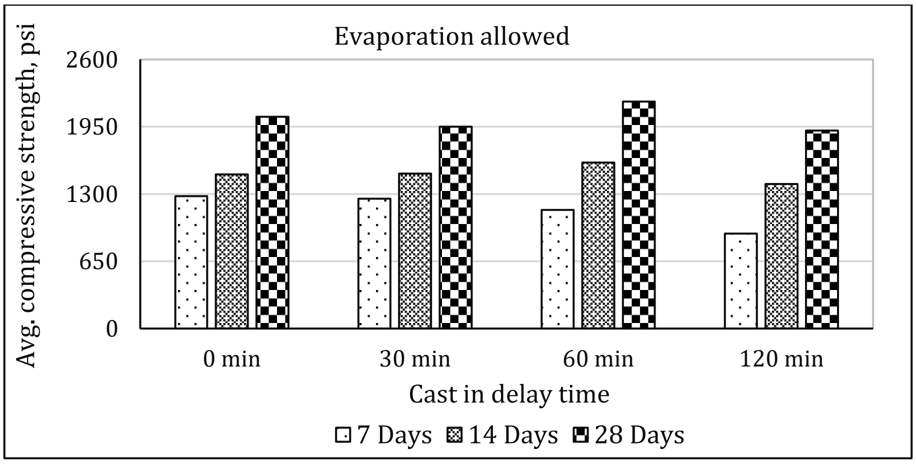

Fig. 6. Variation of CCS with casting delay (PCC, w/c =0.6).

3.2. Effect of casting delay not allowing evaporation

The CCS of the specimens using OPC and PCC with varying casting delays was evaluated, ensuring no evaporation occurred. Figs. 7–10 indicate the change in the compressive strength of concrete specimens made with varying casting delays, without permitting evaporation.

It is evident from Figs. 7–10 that the highest CCS was achieved when OPC had a w/c ratio of 0.5 and the lowest compressive strength was when PCC had a w/c of 0.6.

The maximal strength increases for OPC with a w/c of 0.5 are about 31.3% for seven days at a casting delay of 60 minutes and 36% for fourteen days with a casting delay of 120 minutes. Strength increased by 23% after 28 days with a 60-minute casting delay period. The concrete compressive strength increased by only 11% after seven days with a 30-minute casting delay for a w/c of 0.6. Conversely, with a 120-minute casting delay, the compressive strength increases by 14.9% and 15.7% after 28 and 14 days, respectively.

It is important to note that for OPC, the maximum CCS was obtained at 28 days with 60-minute casting delays. The ideal casting delay period without evaporation in this situation is sixty minutes.

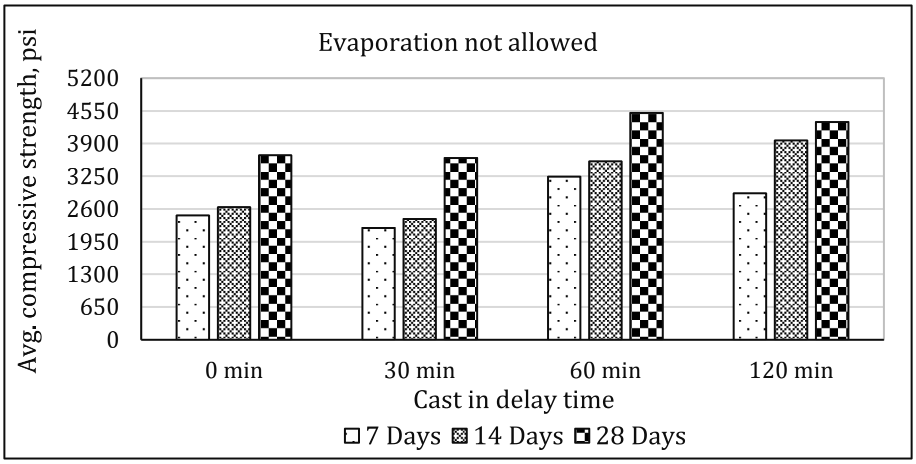

Fig. 7. Variation of CCS with casting delay (OPC, w/c =0.5).

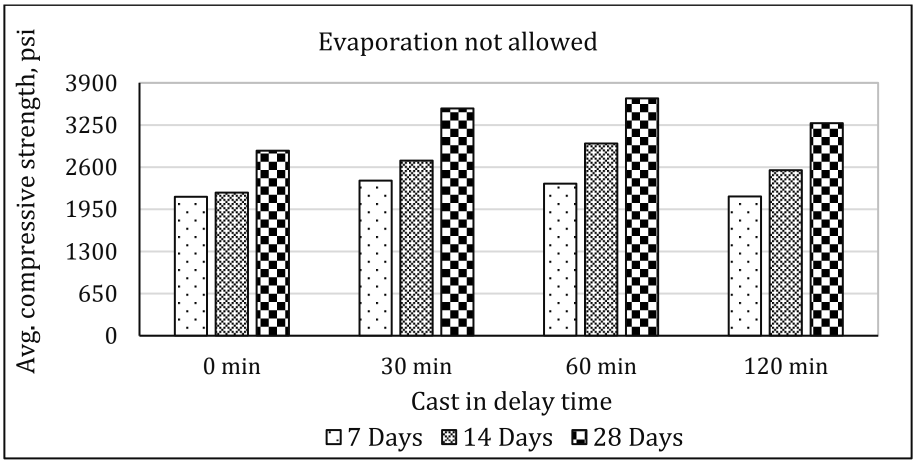

Fig. 8. Variation of CCS with casting delay (OPC, w/c =0.6).

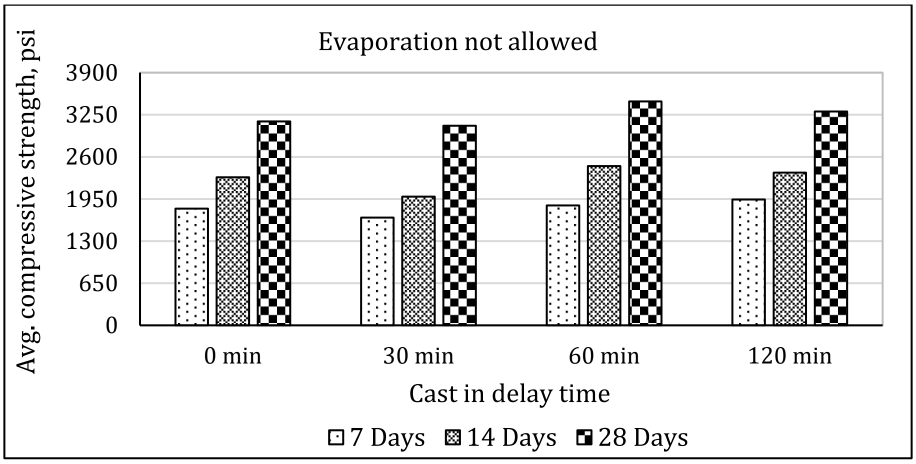

Fig. 9. Variation of CCS with casting delay (PCC, w/c =0.5).

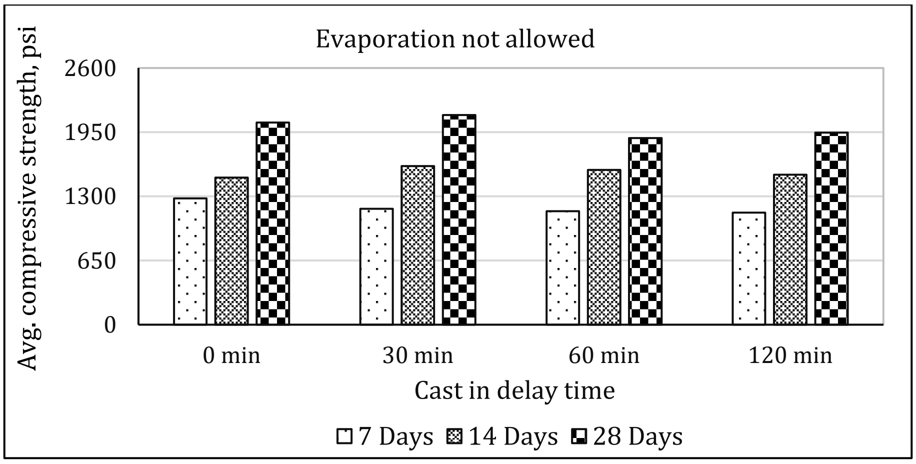

Fig. 10. Variation of CCS with casting delay (PCC, w/c =0.6).

Fig. 9 illustrates that the PCC with a w/c of 0.5 exhibits the highest CCS after 28 days following a casting delay of 60 minutes. In case of 7- and 14-days strength, the effect of casting delay is insignificant. With a w/c of 0.6, casting delay time without evaporation greatly influences the compressive strength of PCC and a decrease in the CCS occurs. Strength was greatly reduced for 7 days concrete, and it was 11.3%; however, for 14- and 28-day concrete, strength was reduced by 2% and 5%, respectively when compared between 120 minutes and zero minutes casting delay (without evaporations).

3.3. Comparison of compressive strength

The comparison of the CCS of OPC and PCC cylinders after 7, 14, and 28 days when evaporation was permitted is shown in Figs.11–13. Among the specimens, OPC with w/c of 0.5 exhibits the maximum strength, whereas PCC with w/c of 0.6 exhibits the lowest strength after 7, 14, and 28 days of curing. At 60- and 120-minute casting delay conditions, the strength of OPC with w/c of 0.6 and PCC with w/c of 0.5 is comparable. Concrete strength decreases as casting delay time increases for PCC with a w/c of 0.6 after seven days, and the lowest strength was found for casting that was delayed by 120 minutes. The greatest strength was found for a 60-minute casting delay for OPC with a w/c of 0.5 at 28 days.

The comparison of the 7-, 14-, and 28-day strengths of OPC and PCC cylinders when evaporation was prohibited is shown in Figs. 14-16. The maximum compressive strength was found for OPC with a w/c of 0.5 and a 60-minute casting delay at 28 days. The PCC with a w/c of 0.6 showed less strength for all casting delay times. Overall, OPC showed highest strength than PCC for all casting delay time and water-cement ratios.

The relative change of the CCS for 120 minutes casting delay time, which is close to the initial setting time, is shown in Figs. 17-18. This percentage strength change was calculated with zero minutes of casting delay. The CCS of cylinder specimens made with OPC shows an increase in compressive strength for both w/c. However, for w/c of 0.6, the concrete specimen made with PCC exhibits the opposite pattern. In this case (PCC, w/c 0.6), the CCS decreased. For PCC with w/c 0.5, the strength change was very similar for 28 days, irrespective of whether evaporation was allowed or not allowed. Overall, the highest percentage change in concrete compressive strength was 14 days in the case of OPC (w/c 0.5). After 120 minutes of delay casting, the strength of OPC with w/c 0.5 decreased a bit. The 28-day concrete strength for PCC with a w/c of 0.6 remained almost constant, irrespective of whether evaporation was allowed or not allowed. PCC showed very little increase in strength with a w/c of 0.5- and 120-minutes casting delay.

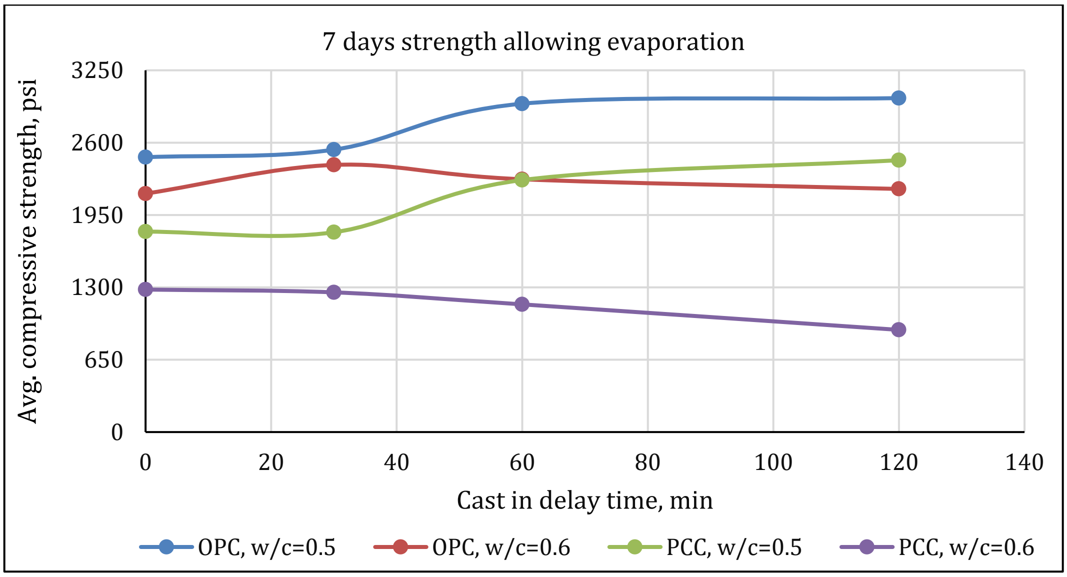

Fig. 11. Variation of 7 days CCS with casting delay.

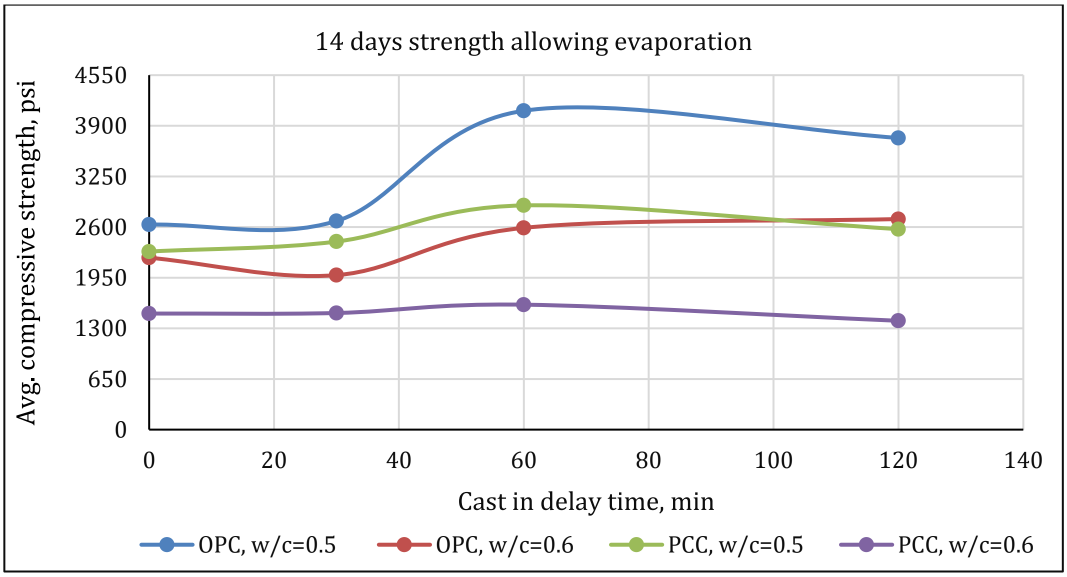

Fig. 12. Variation of 14 days CCS with casting delay.

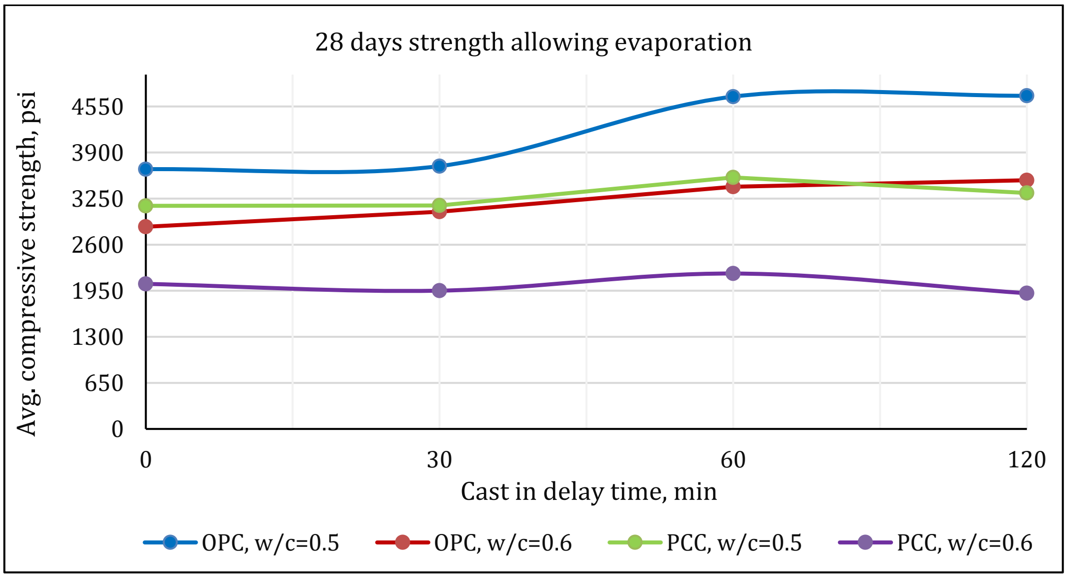

Fig. 13. Variation of 28 days CCS with casting delay.

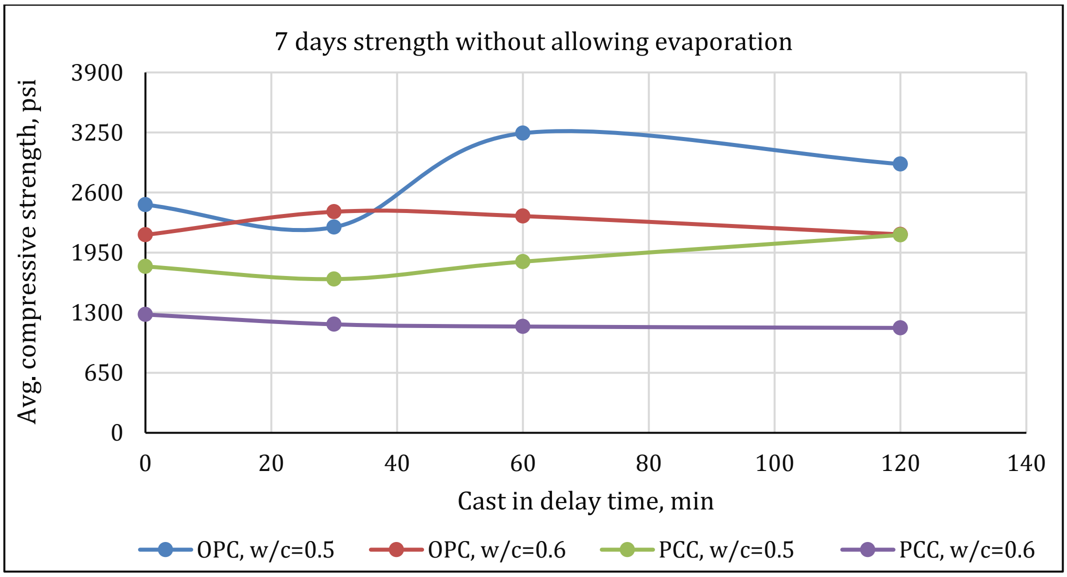

Fig. 14. Variation of 7 days CCS with casting delay.

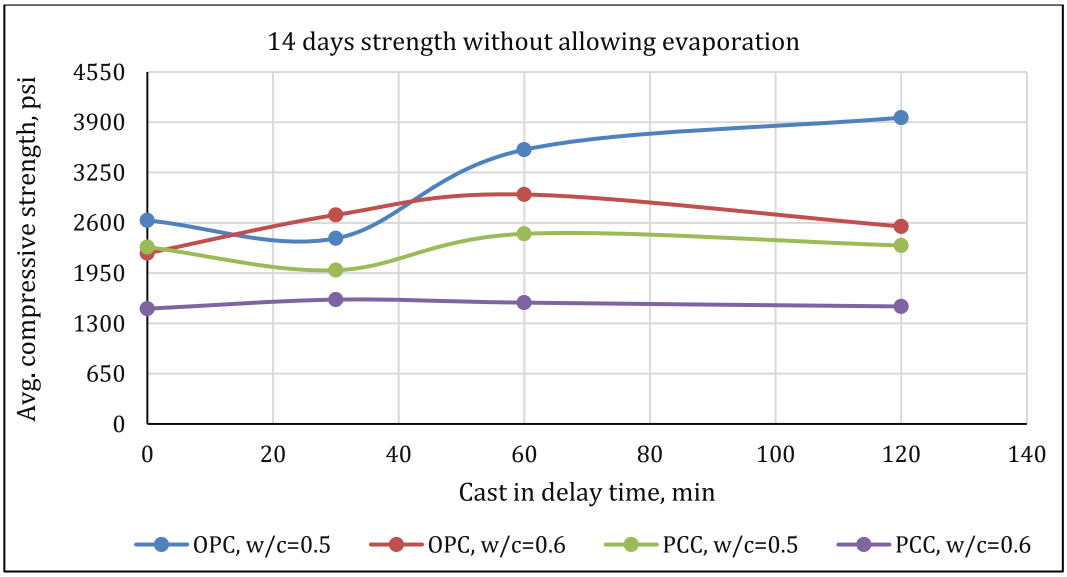

Fig. 15. Variation of 14 days CCS with casting delay.

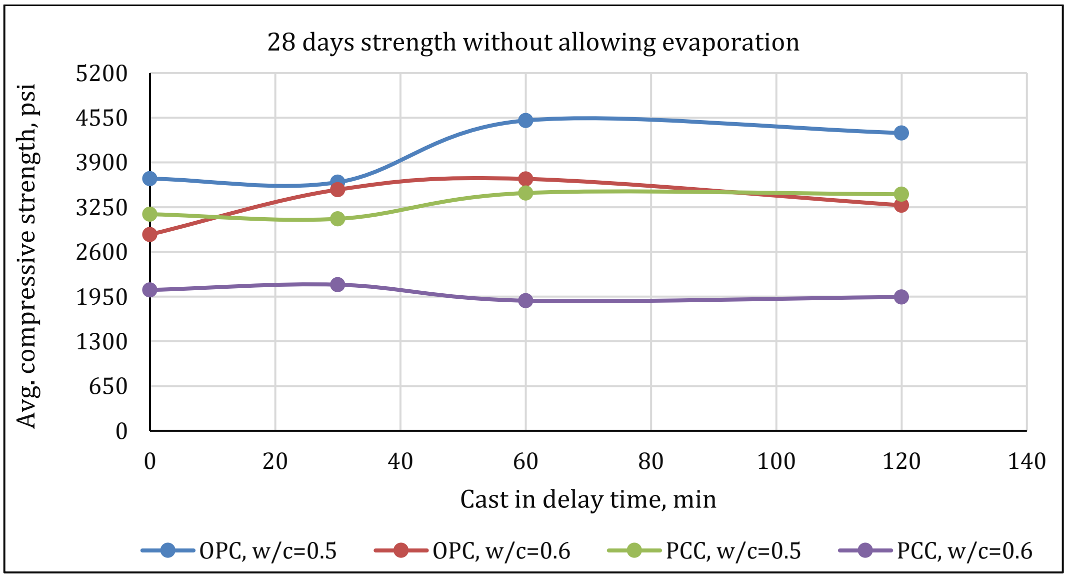

Fig. 16. Variation of 28 days CCS with casting delay.

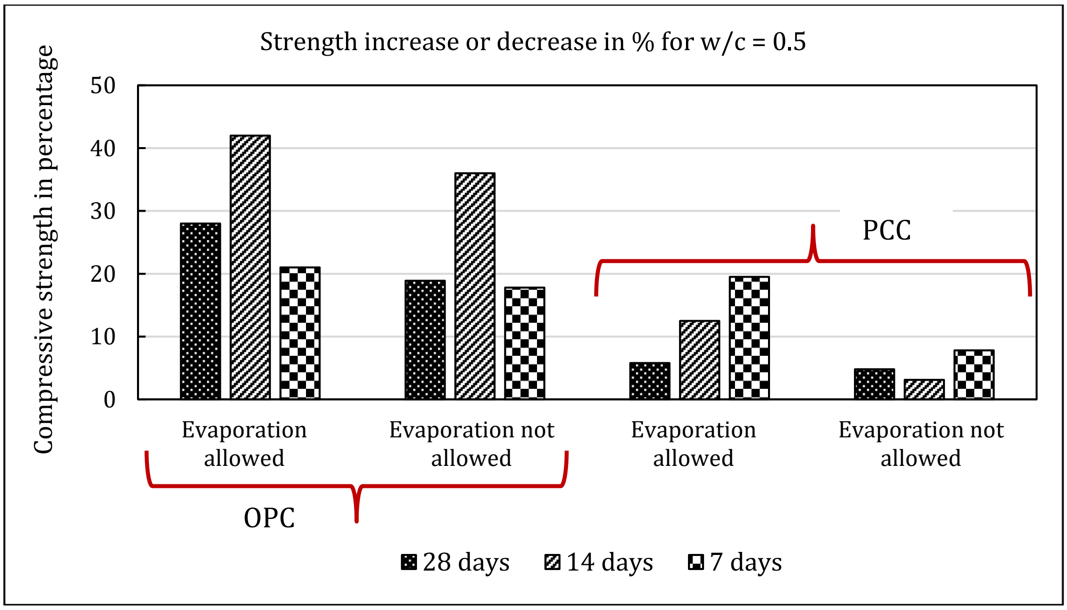

Fig. 17. Compressive strength increase or decrease for 120 min delayed casting for 0.5 w/c.

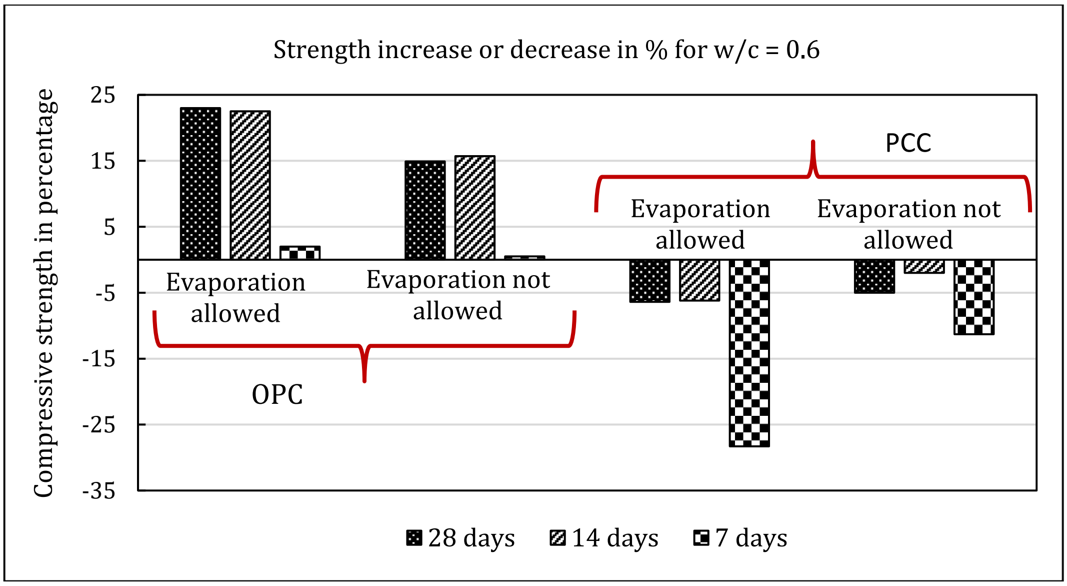

Fig. 18. Compressive strength increase or decrease for 120 min delayed casting for 0.6 w/c.

4. Conclusions

The effect of casting delay on the CCS, with and without allowing evaporation, was investigated in this research. Concrete cylinders were prepared using two types of cement: OPC and PCC, at two w/c, e.g., 0.5 and 0.6. Four casting delay times were considered: 0, 30, 60, and 120 min., to evaluate the influence of delayed casting on strength development. The CCS tests were conducted after 7, 14, and 28 days of continuous cure. The following conclusion can be drawn based on the experimental results:

- The CCS decreased with increasing water-cement ratio. Strength reduction became prominent for a w/c of 0.6, indicating that a w/c of 0.5 provided the optimum strength for both cement types.
- Casting delay influenced strength development differently depending on cement type. For mixtures prepared with OPC, compressive strength generally increased with increasing casting delay time, whereas mixtures prepared with PCC exhibited a reduction in strength with prolonged delay.
- Concrete made with OPC obtained the highest compressive strength, while the concrete made with PCC showed the lowest compressive strength.
- For OPC concrete, both evaporation-allowed and evaporation-restricted conditions produced maximum compressive strength at a casting delay of approximately 60 minutes. A slight reduction in 28-day strength relative to 14-day strength was observed; however, OPC mixtures demonstrated an overall increase in long-term strength sufficient to meet typical 28-day design requirements
- In the case of concrete made with PCC, the optimum w/c is 0.5. Increasing the w/c beyond this value resulted in strength loss. Strength gain was more pro-

nounced at early ages (7 days) compared with later ages (14 and 28 days), suggesting comparatively slower long-term strength development. It can be anticipated that the design strength (28-day strength) might be less than expected.

- Evaporation significantly influenced the compressive strength of concrete. In general, limited evaporation produced a slight increase in compressive strength compared with specimens where evaporation was prevented, likely due to a reduction in concrete pores and an increase of cohesiveness.

Subsequent investigations are advised for future research by examining the data and discussion of the test outcomes from this progressive research. They are: a) Further analysis may be conducted by retempering the mixture with water after the completion of its initial setting period. b) The research may proceed using brick chips. c) Additional study may be conducted by examining various w/c. d) The impact of admixture on casting delay may be examined.

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Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

AI Assistance

No AI-based tools were used in the preparation of this manuscript.

Author Contributions

All authors made substantial contributions to the conception and design of the study, acquisition of data, analysis and interpretation of data; drafted or critically revised the manuscript for important intellectual content; and approved the final version to be published.

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