STRENGTH RECOVERY UNDER DIFFERENT RE-CURING CONDITIONS OF HIGH-STRENGTH CEMENT MORTAR EXPOSED TO HIGH TEMPERATURES

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1. Introduction

High-strength concrete under fire exposure has been shown to suffer greater reduction in residual strength when compared to normal strength concrete, as well as experience explosive spalling [1]. When considering this damage due to fire, it is essential that repairs be made in order to preserve structural integrity. This usually involves the removal of the damaged layers of concrete and casting of new concrete to restrengthen the member [2]. However, re-curing of the damaged concrete in order to recover strength could potentially extend the lifetime of the structure. Strength recovery is possible if the fire-damaged concrete is provided with water, either directly or through a high-humidity environment, in order to reinitiate hydration of the damaged pore structure [3].

This experimental study attempted to determine the variation in flexural and compressive strength of high-strength cement mortar after exposure to high temperatures. The re-curing condition, defined here by the relative humidity (RH) of the re-curing environment (which controls the rate of water supply) and the time after heating, was varied in order to determine the effect of RH and time on strength recovery. In this way, strength recovery behavior after high-temperature exposure could be seen.

2. Experimental program

2.1 Materials

A plain cement mortar mix was used with a water-to-cement ratio of 0.35 and a target 28-day compressive strength of 55 MPa. The complete mix proportions and properties are shown in Table 1. Beam specimens (40×40×160mm) were demolded 24 hours after casting and placed under water, then at 14 days were removed and air cured (60% RH, 20˚C) until high-temperature exposure at 28 or 56 days. A high-range water reducing admixture and air-entraining agent were added to achieve sufficient mix workability.

2.2 High-temperature exposure

Specimens were exposed to high temperatures using an electric furnace. The furnace was preheated to 500˚C, and then the specimens were placed inside, exposed for one hour, and then removed from the furnace.

2.3 Re-curing condition

After exposure, all specimens were air-cooled for one hour until they were safe to handle, then placed in one of four re-curing conditions. 28-day series specimens were re-cured in either air (60% RH, 20˚C) or high RH (90% RH, 25˚C) conditions for 1, 2, 3, 4, and 7 days. 56-day series specimens were subjected to either dry (35% RH, 20˚C) or water (saturated, 20˚C) re-curing conditions, then tested after 1, 2, 3, and 7 days.

2.4 Strength testing

Specimens were tested for residual flexural and compressive strengths following JIS R 5201-1997 procedure. After re-curing, mortar beams were first tested in flexure using single-point loading, then half the flexural specimen was recovered and tested in compression.

Table 1 Mortar Mix Proportion and Properties

Cement (kg/m^3) Ordinary Portland Type I	C	738
Water (kg/m^3)	W	258
Fine aggregate (kg/m^3) Natural river sand	S	1329
Air entraining agent (%C by weight)	AE	0.4
High-range water-reducing admixture (%C by weight)	HRWA	1.0
Water/cement ratio	W/C	0.35
Sand/cement ratio	S/C	1.8
Avg. 28-day comp. strength (MPa)	53	
Avg. flow (mm)	22.6	
Avg. air content (%)	6.8	

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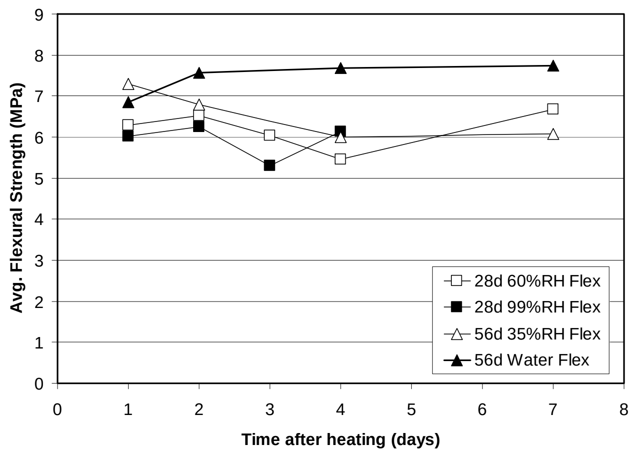
3. Results and discussion

3.1 Flexure test

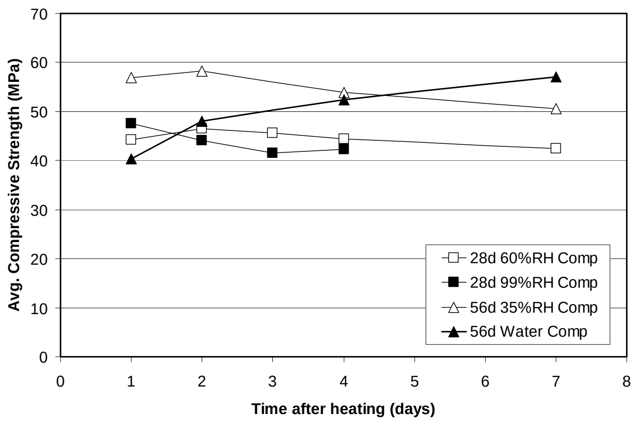
Flexure test results are shown in Figure 1(a).

Behavior between the RH specimens at both 28 and 56 days were similar. Flexural strength generally decreased at a similar rate for all specimens between 1 and 3 days. However, the point at which strength recovery began varied depending on the RH. For 99% RH, an increase of 0.8 MPa occurred between days 3 and 4. For 60% RH, an increase of 1.2 MPa occurred between days 4 and 7. For 35% RH, no strength increase was observed, but there was a little change between days 4 and 7, indicating a tapering of the strength loss.

This behavior demonstrates a relationship between the amount of water supply through the re-curing environment and the onset of flexural strength recovery. Higher RH or water submersion resulted in earlier occurrence of strength recovery, thus showing that supplying high levels of moisture through the re-curing atmosphere accelerated the flexural strength recovery process.



(a)



(b)

Figure 1 (a) Flexural and (b) compression test results

3.2 Compression test

Compression test results are shown in Figure 1(b).

Water-cured specimens showed constant strength development, increasing 16.8 MPa by day 7. This strength increase is significant when compared to the RH specimens, which showed almost no strength gains within the 7-day period. The 56-day 35% RH specimens and the 28-day 60% RH specimens showed almost identical behavior over time, decreasing by 6.3 and 1.8 MPa, respectively, from day 1 to day 7. The difference in the two series can be attributed to the difference in curing time of the 56-day series. A small strength gain could be observed in the 99% RH specimens after 3 days.

Unlike the flexural strength, the compressive strength did not increase for all series; only the water and 99% RH series experienced strength recovery, and both series' behavior was similar to the flexural strength. However, the lower RH series exhibited a consistent and similar downward trend. This is possibly due to the compressive strength recovery mechanism requiring a greater supply of water or a longer re-curing period before initiation of strength recovery.

4. Conclusions

The effect of cooling condition on the residual flexural and compressive strengths of high-strength cement mortar was shown. Flexural strength recovery could be seen even at low RH levels, and the time delay in onset of strength recovery decreased with increasing RH. Compressive strength behavior appeared to be less sensitive to the RH of the re-curing environment, as similar behavior was observed between the lower RH series. It was also seen that both flexural and compressive strength of specimens re-cured in water underwent constant strength increases over the measurement period.

References

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