Effect of Mixture Ratios on Thermal Behaviours of High Strength Concrete Walls Exposed to Fire on Foreside

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Abstract. This paper aims at evaluating thermal behaviors of high strength concrete walls exposed to fire on foreside having different mixture ratios. Toward that goal, fire tests of walls are performed on concrete walls for 2 hours in heating furnace according to the international standard ISO-834. Variables of the study are mixture ratios and locations of thermocouples. First, two different mixture ratios are used for high compressive strength concretes with targeting 28 days compressive strength of 40MPa and 60MPa. One of the mixtures (targeting 28 days compressive strength of 60MPa) includes Polypropylene fibers to prevent explosion. Second, 12 thermocouples are installed at 3 different locations of concrete walls and each location has thermocouples at 3 different distances from the fire exposed surface (20mm, 40mm and 100mm). Size of the wall is 1200mm (H) x 600mm (W) x 200mm (T). From the fire tests, time-temperature curves are obtained at different locations. The test results show that temperatures vary depending on locations and are significantly affected by mixture ratios.

1. Introduction

The high strength reinforced concrete walls over compressive strength over 40MPa are mostly used for resisting against lateral force in Korea. Especially the concrete walls have high strength used for the high-rise residential buildings built recently are key role of structural safety of the buildings. Concrete Standard Specification of Korea defines concrete over compressive strength 40MPa as a high strength concrete. Particularly concrete over compressive strength 50MPa has higher probability of causing danger raised by spalling compare to normal strength concrete when there is fire accident as well known. Ngo et al. (2013) found the differences in thermal behavior between normal and high strength concrete walls for ISO 834 standard fire testing. Specifically, it was observed that high strength concrete walls suffered severe damage due to spalling than normal strength concrete walls. Also wall has high chance of getting structural damage if it is exposed to fire because it has large area to get damaged compare to structural members such as columns and beams. There are some researches about behaviors of column and beam exposed to fire in abroad but relatively not many researches have studied behaviors of wall exposed to fire. Lee and Lee (2013) conducted experimental and numerical studies of the fire resistance of concrete walls with various height to thickness ratios, concrete strengths and axial load levels. In their studies, the fire resistance of concrete walls was predicted based on the experimental observations of
columns exposed to elevated temperatures. Thus it is important to find if mixture ratio of concrete has influence to temperature rising of the wall when the wall exposed to fire. Also studying how temperature of wall changes and the wall behaves when it is exposed to fire.

Toward this goal, fire tests are performed on concrete walls having different mixture ratios for 2 hours according to international standard ISO-834. In the experiments, temperature distributions are measured through 3 different locations with 3 different depths from surface of wall exposed to fire at every thermocouple.

2. Experimental Programme

2.1. Materials

The mix proportion used in the fabrication of concrete walls is presented in table 2. Test variables are mixture ratios such that the 28 days targeting compressive strength are 60MPa and 40MPa. Polypropylene is added only to the mixture ratio of the specimen targeting 28 days compressive strength of 60MPa to prevent spalling during fire test. After concrete pouring, specimens are cured for 4 months at a room temperature.

| Specimen  | Standard | Strength (MPa) | W/B (%) | Unit Weight (kg/m³) |
|-----------|----------|----------------|---------|---------------------|
| 60W-T0    | 25-60-600| 60             | 26.6    | 160                 |
| 40W-T0    | 25-40-600| 40             | 34      | 163                 |

2.2. Design of Specimens

Wall specimens are fabricated to investigate the difference of temperature distributions between two specimens having different mixture ratios. The wall thickness is 200mm, considering the general wall thickness of residential buildings in Korea. The dimensions of the wall specimens are 600mm and 1,200mm for width and height, respectively. The height of the walls is determined in order to avoid the buckling effect of walls. The thermocouples are placed on 3 different such as middle, top and side points from the front view, and each location has 3 thermocouples at 3 different depths in 20mm, 40mm and 100mm from the surface of walls exposed to fire. The total number of thermocouples is 9 at each wall. Details of the test specimens and the location of thermocouples are shown in figure 1.

| Specimen | Strength (MPa) | Thickness (mm) | Heating Hours(h) | Heating Side   |
|----------|----------------|----------------|------------------|----------------|
| 60W-T0   | 60             | 200            | 2                | Foreside only  |
| 40W-T0   | 40             |                |                  |                |
Figure 1. Design of walls and Locations of thermocouples (unit: mm)

2.3. Test set-up
Two wall specimens are fabricated to investigate the difference of temperature between two different mixture ratios. One of the mixture ratios is targeting 28 days compressive strength 60MPa, the other mixture ratio is targeting 28 days compressive strength 40MPa. Figure 2 is process of casting concrete. Figure 3 is specimens before fire test and Figure 4 is specimens placed in the heating furnace.

Figure 2. Fabricating Process
2.4. Test Set-up and Data Measurement

Fire test is performed in the fire furnace as shown in Figure 5. The specimens are heated on the foreside for 2 hours according to the ISO standard heating curve, as illustrated in figure 7. Concrete blocks is used to keep the heat on to the specimens illustrated in figure 6.

Figure 3. Specimens before test  
Figure 4. Specimens in heating furnace  
Figure 5. Cross-sectional view of Fire test set-up of specimens in the fire chamber
3. Result and Discussion
After 2 hours of fire test, time-temperature graphs are obtained as illustrated in figure 9. Figure 9 presents temperature at A, B and C locations in depth 20mm from fire exposed surface. It is obvious that wall of mixture ratio targeting 28 days compressive strength of 60MPa has higher temperature than the wall of mixture ratio targeting 28 days compressive strength of 40MPa at every location during 120mins. It is because polypropylene fibers melt early and that makes pores. The temperature rises through the pores. And thermocouples at C shows the highest temperature among locations. Medium temperatures are measured from A, and lowest temperature are observed from B. Table 3 shows the difference of temperature between locations of both walls at 30 minutes, 60 minutes, 90 minutes and 120 minutes. In wall targeting 28 days compressive strength of 60MPa, at 60 minutes, temperature of C1 is approximately 50% higher than B1 and at 120mins, temperature of C1 is approximately 62% higher.
than B1. In wall targeting 28 days compressive strength of 40MPa, at 60 minutes, temperature of C1 is approximately 50% higher than B1 and at 120mins, temperature of C1 is approximately 57% higher than B1. The result shows location C has higher temperature than location A and B. It is because upper Flange side of location A and B is covered with insulation to make upper head of the wall not to get heat. It is inferred that insulation delays temperature rising of A and B.

![Time-Temperature Graph](image)

**Figure 9.** Time-Temperature Graph comparing at A1, B1 and C1

| Time (min) | Temperature (℃) |
|------------|-----------------|
| 60W_A1     | 30              | 244.7          |
| 40W_A1     | 60              | 128.1          |
| 60W_B1     | 90              | 170.8          |
| 40W_B1     | 120             | 113.8          |
| 60W_C1     | 30              | 461            |
| 40W_C1     | 60              | 357.4          |
| 60W_C1     | 90              | 748.2          |
| 40W_C1     | 120             | 562.3          |

**Table 3.** Temperatures of A1, B1 and C1

4. **Conclusion**

To investigate the effect of concrete mixture ratios, two walls are heated on foreside according to the ISO 834 standard fire curve. The thickness of wall is 200mm and cross sectional temperatures are measured at three different locations (A, B and C) through 3 different depths from exposed surface of wall during heating. The experimental results clearly show the temperature of the wall with mixture ratio targeting 28 days compressive strength of 60MPa is higher than the wall with mixture ratio targeting 28 days compressive strength of 40MPa. It is because the higher the compressive strength, the distance between molecules of concrete is closer so transmission of the heat is more effective.
5. References

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