# COMPARATIVE ANALYSIS OF HIGH STRENGTH CONCRETE AND NORMAL STRENGTH CONCRETE COLUMNS EXPOSED TO FIRE

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***Abstract -*** *The increased usage of high strength concrete in buildings has resulted in concern regarding the behavior of such concrete under fire. In particular, spalling at certain temperatures, as identified by performing a fire test on concrete columns in laboratories, is of particular concern. This paper provides comparative analysis of structural behavior and the principal influences of high temperature in concrete at loss of compressive strength and spalling, the unintended discharge of material from a member of high strength concrete (HSC) column and normal strength concrete (NSC) columns. Though a lot of information has been gathered on both phenomena, there remains a need for a broader understanding of the response of concrete structures to different heating rates and the performance of complete concrete structures subjected to realistic fire exposures. There is a lack of information derived from large-scale tests on concrete buildings in natural fires. So we are experimenting fire test on Four Reinforced (normal strength and higher strength) concrete columns in laboratory to get actual behavior of concrete columns.*

*Key Words*: High Strength Concrete, Normal Strength Concrete, Structural behaviour, Spalling, Fire resistance.

## 1. INTRODUCTION

Current concrete design Codes raise concerns about concrete spelling during fire particularly under compressive stresses and high heating rates. High strength concrete columns would be more prone for explosive spelling due to their low permeability and high brittleness. This paper represents an experimental program on the behavior of high strength concrete columns under fire. The research includes testing reinforced high strength concrete columns subjected to various loading levels and heating rates. We used to trace the structural behavior of reinforced concrete columns at elevated temperatures. A comparison is made of the fire resistance performance of High strength concrete (HSC) columns with that of normal strength concrete (NSC) columns. The factors that influence the thermal and structural behavior of HSC concrete columns under fire conditions are discussed. The results presented will generate data on the fire resistance of high performance concrete columns and contribute to identifying the difference in behavior between HSC and NSC columns.

## 2. RESEARCH SIGNIFICANCE

The objective of this paper is to report the main outcomes of experimental study on the effect of loading and heating rates on explosive spalling and structural and physical behavior of high strength concrete columns and normal strength concrete column under fire. The paper includes the test methodology, main results, conclusions and measured parameters including temperatures of high strength concrete column and normal strength concrete column.

## 3. THE EXPERIMENTAL STUDY

### 3.1 Test Specimens

The tests involved main 4 reinforced concrete columns of a section 150mm x 150mm and 720 mm height. Each column was reinforced with four 12mm diameter steel bars and connected with 6 steel ties (8mm diameter) at 100 mm intervals. Ties were located more often near the ends to prevent any possible local column failure near the loading points.

**Table-1:** Batch quantities and properties of concrete mix

| Sr.No | Properties | Batch (Specimen type) | | | |
|---|---|---|---|---|---|
| | | NSC 1 | HSC 1 | HSC 2 | HSC 3 |
| 1 | Column steel (%) | 1.5 | 1.5 | 1.5 | 1.5 |
| 2 | Cement content (kg/m3) | 128 | 110 | 141 | 116 |
| 3 | Fine aggregate (kg/m3) | 316 | 223 | 240 | 296 |
| 4 | Coarse aggregate (10mm) (kg/m3) | 334 | - | 471 | 415 |
| 5 | Light wt. aggregate (5-10mm) (kg/m3) | - | 475 | - | - |
| 6 | Aggregate type | Siliceous | Siliceous | Siliceous | Siliceous |
| 7 | Water (kg/m3) | 86 | 78 | 71 | 80 |
| 8 | Water binder ratio | 0.34 | 0.34 | 0.34 | 0.34 |
| 9 | Fiber (kg/m3) | - | - | 2 | - |
| 10 | Fiber type | - | - | Polypro pylene | - |
| 11 | Silica fume (kg/m3) | - | - | - | 1.952 |

NSC : Normal Strength Concrete
HSC1: High strength Concrete (light weight aggregate)
HSC2: High strength Concrete (polypropylene fiber)
HSC3: High strength Concrete (Silica Fume)

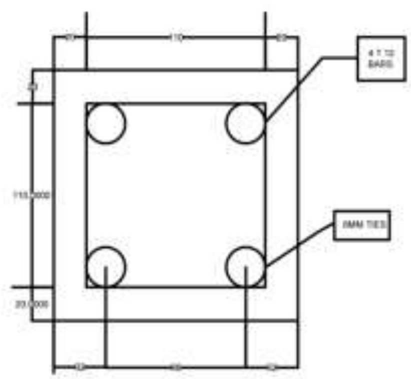

**Fig-1:** Dimensions of Column section of HSC and NSC

We use tested Type 10 Portland cement and other all tested materials like coarse aggregate and fine aggregate, water and good quality of other cementitious material like fiber and silica fumes. The average compressive cylinder strengths of the concrete, measured 7 and 28 days after pouring and on the day of the testing. The moisture condition at the center of the column was also measured on the day of the test.

The tests were carried out by exposing the columns to heat in a furnace specially built for testing loaded columns. The furnace consists of a steel framework supported by four steel columns, with the furnace chamber inside the framework. The test furnace was designed to produce conditions, such as temperature, structural loads and heat transfer, to which a member might be exposed during a fire.

**3.2 Test Apparatus**

The decreased fire resistance for HSC columns and NSC column can be attributed to the thermal and mechanical properties of HSC. Further, the spalling phenomenon, which resulted in the decrease in the cross-section of the column, also contributed to lowering the fire resistance in the HSC columns. It can be attributed to the type of aggregate and other materials used in the concrete mix, as explained above.

### 3.3 Test Conditions and Procedure

The columns were installed in the furnace. Each column, exposed to fire was from all the sides. At high temperature, the stiffness of the unheated column ends, which is high in comparison to that of the heated portion of the column, contributes to a reduction in the column effective length. In previous studies, it was found that, for columns tested fixed at the ends; an effective length of 2000 mm represents experimental behaviour.

**Fig-2**: RCC columns Under Fire

The load was applied approximately 45 min before the start of the fire test and was maintained until a condition was reached at which no further increase of the axial deformation could be measured and while columns were in fire the colour changes, formation of cracks, spalling type and time-temperature is observed. After the fire test compression test were taken after 24 hours.

**Fig-3:** Compression test on RCC columns after fire

### 3.4 RESULTS AND DISCUSSION

After testing the specimens, the temperature-time curves are to be plotted for the external surface and for various depths in concrete columns HSC1, HSC2, HSC3 and NSC1 respectively. The measured temperature in the furnace followed the standard temperature-time curve. Reason of failure of the columns is to find out.

All three columns failed in compression mode or in tension mode were observed. In the NSC and HSC column, significant spalling occurred until the failure of the column is find out which is shown in table-4.

For accurate modelling to predict spalling, pressure-temperature relationship is required. However, such data is not well documented in the literature at present. Hence in design codes and standards a simplified approach is used in order to minimize the risk of spalling. Based on detailed experimental studies on HSC columns, it was found that spalling occurs when temperatures in concrete reach above 350ºC. However, the Euro code states a value of 500ºC for the NSC spalling limit. It seems that spalling is likely to occurs in the column surface zone when the temperature reaches 350ºC, and after sufficient time duration the spalling zone spreads toward the centre. Data from the experimental studies also showed that, while spalling occurs throughout the cross-section in the case of columns with straight ties, spalling occurs only outside the reinforcement core when the ties are bent in to the concrete core.

Further, the addition of fibers to concrete helps in minimizing the extent of spalling in HSC members. The presence of polypropylene in concrete influence the extent of spalling. The polypropylene fibers melt at relatively low temperatures (about 167-170°C) and create randomly oriented micro and macro channels inside concrete.

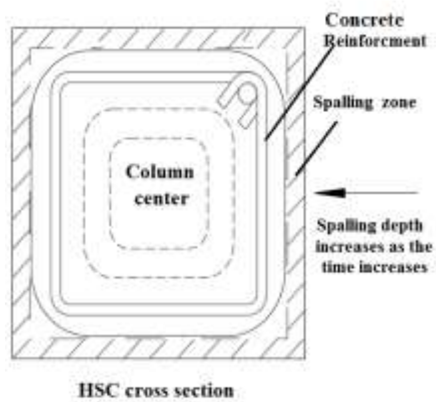


**Fig-4:** spalling zone and spalling depth increase direction.


Fig-4: Spalling of column before and after


**Fig -4**: HSC and NSC column after fire

**Table-2:** Colour Changes of the specimen

| Column | Time(min) | Temperature ($^0$C) |
|---|---|---|
| NSC 1 | 33 | 282 |
| HSC 1 | 36 | 302 |
| HSC 2 | 49 | 346 |
| HSC 3 | 41 | 329 |

**Table-3:** Formation of cracks on surface of column

| Column | Time(min) | Temperature ($^0$C) |
|---|---|---|
| NSC 1 | 48 | 431 |
| HSC 1 | 52 | 492 |
| HSC 2 | 67 | 499 |
| HSC 3 | 66 | 503 |

**Table-4:** Result for spalling

| Column | Spalling type | Time (min) | Temperature (0C) |
|---|---|---|---|
| NSC 1 | Minor | 79 | 481 |
| HSC 1 | Major | 88 | 503 |
| HSC 2 | Minor | 108 | 576 |
| HSC 3 | Severe | 98 | 587 |

## 4. CONCLUSIONS

1. The behavior of HSC columns at high temperature is significantly different from that of NSC columns. The fire resistance of HSC columns is lower than that of NSC column.
2. The addition of Polypropylene fibers in HSC can improve the ductility of HSC columns and increases their fire endurance.
3. The presence of Polypropylene fibers and Silica fume in HSC columns can reduce spalling and enhance the fire resistance.

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