

NISTIR 6890

**Fire Resistance Determination and
Performance Prediction Research
Needs Workshop: Proceedings**

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Fire Resistance Determination and Performance Prediction Research Needs Workshop: Proceedings

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NRC-CANADA

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Fire Resistance Evaluation of Large-scale Structural Systems

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Outline

- Background
- Current Research Projects
- Fire Performance of HSC
- Experimental Studies
- Factors Influencing Fire Performance
- Design Guidelines
- Trends, Needs, Directions

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Fire Safety

- Buildings - Design requirements
 - Fire - Severe conditions
 - Fire safety
 - loss of life and property
- Fire resistance - structural elements
 - safe evacuation of occupants & fire personnel
 - minimize property damage
 - control spread of fire
- Modern buildings

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Floor Assembly after FR Test in Floor Furnace



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Steel Stud Wall Assembly in Wall Furnace



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Steel Stud Wall Assembly in Wall Furnace



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Intermediate Scale Furnace - Walls & Floors



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High Strength Concrete

- Superior Performance
 - High strength
 - Durability
- Applications
 - Bridges, Infrastructure Projects
 - Buildings - Columns

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HSC Exposed to Fire

- NSC - good fire resistance
- HSC - behaviour of different from NSC
- Spalling
 - low porosity, high density
 - pore pressure
- No guidelines on HSC exposed to fire
 - NBCC, ACI 318/216, CSA-A23.3
- Eliminate fire protection

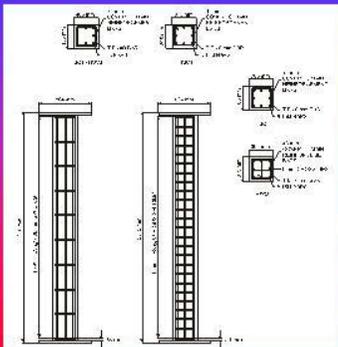
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Experimental Studies

- RC columns - HSC, NSC
- Test variables
 - 28-day compressive strength
 - siliceous, carbonate aggregate
 - reinforcement configuration - ties
 - size
 - load intensity
 - fibre reinforcement
 - fire intensity

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Elevation & C.S. Details of HSC Columns



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Fire Resistance Experiments

- full-scale specimens
- designed to code specifications
- loads, ends conditions
- std. time-temperature (ASTM-E119/E1529)
- temperatures, deflections, fire resistance
- spalling

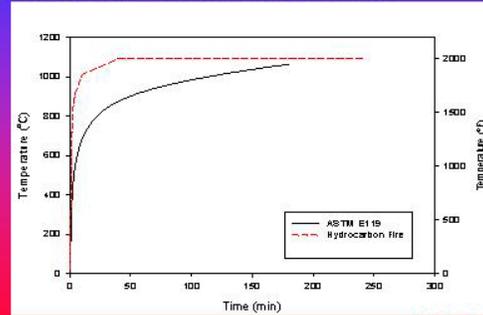
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Column Furnace



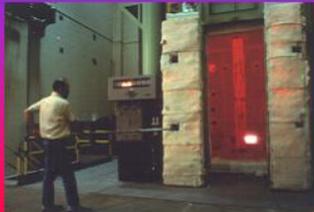
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ASTM E119 and E1529 (Hydrocarbon Fire) Exposure for Fire Resistance Tests



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HSC Column after Fire Resistance Test



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Spalling in HSC

- Not significant in early stages (30 min)
 - very minimal in columns with 135° ties
- Spalling progression (1-2 hrs)
 - hair line cracks, widen at corners
 - chunks falls off (ties not at 135°)
- Significant towards end of test (failure)
 - ties open up, buckling in rebars
 - Much higher in columns with ties 90°

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Post-failure Observations

□ NSC Column

- ties did not open up
- less buckling of rebars
- less spalling
- failure confined to locally

□ HSC Column

- ties opened up
- buckling of rebars
- significant spalling - cross-section loss
- failure over length of column

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View of HSC2 after Fire Test



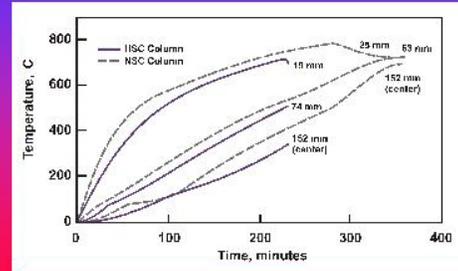
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View of HSC6 after Fire Test



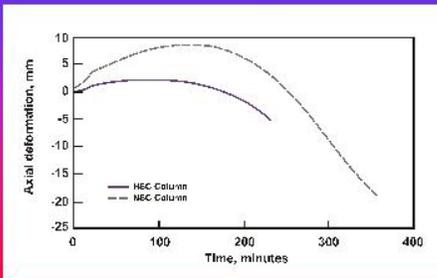
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Variation of Temperature with Time in NSC and HSC Columns Exposed to Fire



ARC-CIRC

Variation of Deflection with Time in NSC and HSC Columns Exposed to Fire



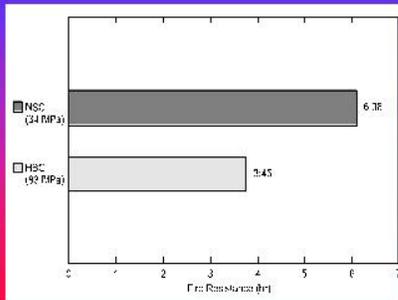
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Factors Influencing Fire Performance

- Compressive strength
- Reinforcement layout
- Moisture content (RH)
- Concrete density
- Heating rate (fire intensity)
- Aggregate type
- Load Intensity, Type
- Fibre reinforcement

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Effect of Strength



Higher Concrete Strength
 • Decreases Fire Resistance
 • Enhances Spalling

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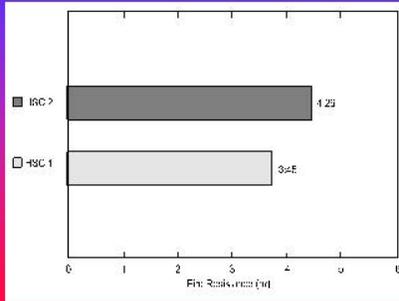
View of NSC and HSC Columns after Fire Resistance Tests



(a) Normal strength concrete column (b) High strength concrete column

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Effect of Rebar/Tie Layout

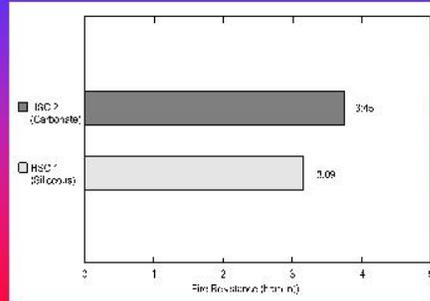


• Closer Tie Spacing, Improved Configuration

- Enhances Fire Resistance
- Reduces Spalling

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Effect of Aggregate Type

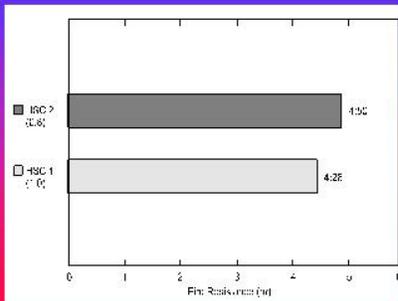


• Carbonate Aggregate

- Enhances Fire Resistance
- Minimizes Spalling

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Effect of Load Intensity

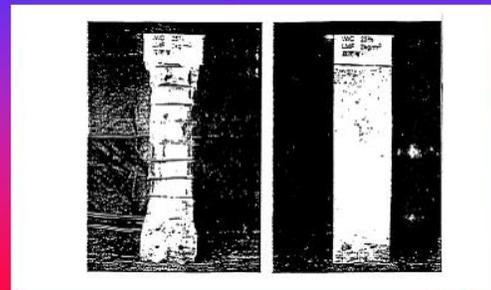


• Higher Load Levels

- Decreases Fire Resistance
- Promotes Spalling

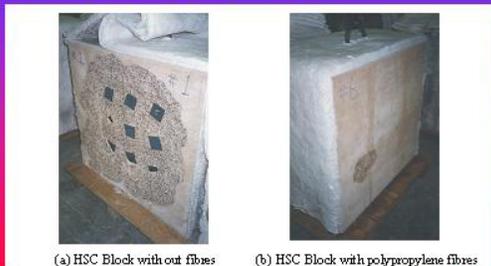
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View of HSC Columns With and Without PP Fibres



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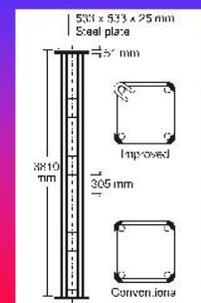
View of HSC Blocks, with and with out fibres, after two hour Hydrocarbon Fire Tests



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Design Solutions

- HSC columns
- Reinf. detailing
 - tie configuration
 - bending ties @ 135°
 - tie spacing - closer
 - cross ties
- minimizes spalling
- enhances FR



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Cures (Solutions) – Spalling

- Carbonate aggregate (limestone)
- Normal density aggregate
- Sufficient concrete cover
- Lower load intensity; eccentricity

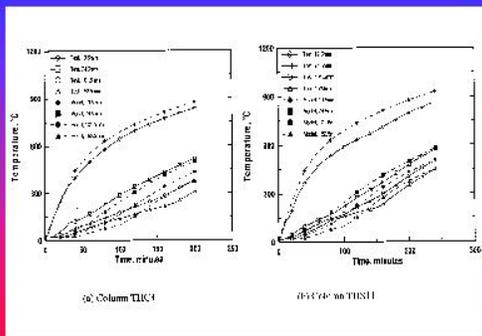
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Numerical Studies

- Material properties at elevated temp.
 - Thermal and mechanical properties
- Computer program
 - Predicting the behaviour of HSC columns
- Parametric studies
 - Factors influencing the behaviour
 - Design equations for fire resistance
 - Integration with structural design

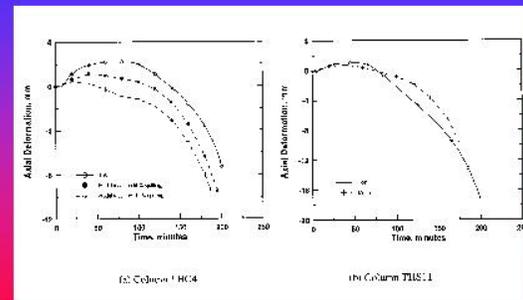
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Temperatures from model & test



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Axial deformation from model & test



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Collaborations

- Concrete Canada
- CCA
- PCA
- CANMET
- MOBIL R and D Corp. Tech. Inc
- NCTU, Taiwan

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Future Trends, Industry Needs, Research Directions

- Fire Resistance - Realistic Considerations
 - tools for analysis, fire scenarios
 - validated models, design fires, properties
- Performance-based Codes
 - calculation methods
 - design guides, software packages
- High Performing Materials
 - satisfy fire resistance - governing factor
 - Practical & cost-effective solutions

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