Application of High-Strength and High-Performance Concrete in Seismic Regions

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APPLICATION OF HIGH-STRENGTH AND HIGH-PERFORMANCE CONCRETE IN SEISMIC REGIONS

Outline of Presentation
1) Backgrounds
JCI Technical Committee on Structural Performance of High-Strength Concrete Structures Utilization of High-Strength and High-Performance Concrete
2) Seismicity around Japan and EQ Damage
3) Overview of Application of HSC/HPC in Japan
High-Strength Concrete
High-Strength Fire-Resistant Concrete
High-Performance Concrete
Self-Compacting Concrete
High-Durability Concrete
High-Ductility Concrete
4) Concluding Remarks

JCI Committees on HSC/HPC

Structural Performance of HSC Structures (2004.4 - 2006.3)
To review the state of research and design of HSC structures
To prepare technical reports of structural performance of HSC structures.
Subcommittees on “structural performance” and “structural design”

Utilization of HSC/HPC (2006.4 - 2008.3)
To review the state of research, design and application of HSC/HPC
To prepare keynote papers for HSC/HPC Symposium
Subcommittees on “high-strength & fire-resistance”
Self-compacting & high-durability
Fiber-reinforced & high-ductility

High-Strength Concrete (HSC)
High-Performance Concrete (HPC)
The “high-strength concrete” added with “high-function” such as:
high-durability,
high-ductility,
self-compacting,
fire-resistance.

BHSC/HPC Keynote Lectures

From Japan Concrete Institute (JCI)
Subcommittees on High-strength & Fire-resistant
K1: Mechanical Properties of Concrete and Reinforcement (Prof. Nishiyama, Oct.27 am)
K2: Self-Compacting & High-durability
K3: High-Durable Concrete in Japan (Dr. Yokota, Oct.27 pm)
K4: Self-Compacting Concrete in Japan (Prof. Ohuchi, Oct.27 pm)
K5: Concrete on Fiber-reinforced & High-ductility
K6: Review of Japanese Recommendations on Design and Construction of Different Classes of Fiber Reinforced Concrete and Applications Examples (Prof. Uchida, Oct.28 am)

From Japan Prestressed Concrete Engineering Association (JPCEA)
Committee on Design and Construction of Prestressed Concrete Structures Using High-strength Concretes
K7: Outline of “Guidelines for Design and Construction of High-strength Concrete for Prestressed Concrete Structures” (Prof. Matsuyoshi, Oct.28 pm)

From fédération internationale du béton (fib)
Commission B on Concrete
K8: Constituting modeling of HSC/HPC - a survey on fib Bulletin 42 (Prof. Devin, Oct.29 pm)

BHSC/HPC Invited Lectures

From Europe (Af)
Professor Jospe Wulven, Delft University of Technology, THE NETHERLANDS
High Performance Fibre Concrete: a material with a large potential

From America (ACh)
Professor John J. Myers, Missouri University of Science and Technology, USA
The Use of High Strength / High Performance Concrete in America: A Code and Application Perspective

From Europe (Af)
Dr. Tor Arne Hammer, CON - Concrete Innovation Centre by SINTEF, NORWAY
Future HPC - Driven by Industrial Need for Innovation as well as Environmental and Social Needs

From Asia (ACF)
Professor Takanori Shimomura, Nagoya University of Technology, JAPAN
High Strength and High Performance Concrete in the Asian Countries and Regions

Seismicity around Japan
Population: 127 billion—High population density
Land area: 378,005 km² (smaller than California)
Length from N to S: 3,500 km (1,800 miles)
Extends along the borders of four major plates

Seismicity EQ Damage
High-Strength Fire-Resistant Self-Compacting High-Durability Fiber-Reinforced High-Ductility

Concluding Remarks
Application of High-Strength and High-Performance Concrete in Seismic Regions
We sit on a high density seismic area. We have to prepare for big earthquakes.

Recent Earthquake Records

- 1923 Kanto (M7.9)
- 1948 Fukui (M7.1)
- 1954 Niigata (M7.5)
- 1968 Tokachi-oki (M7.9)
- 1995 Kobe (M7.2)

Chronology and Impact of Major Earthquakes

Damage to RC Buildings due to 1968 Tokachi-oki Earthquake

- Damage to many RC buildings due to shear failure of short columns
- After the earthquake: Revision of concrete standard
- Revision of building law
- Investigation of seismic behavior of RC buildings

Engineered mid-rise RC and SRC buildings experienced full-story-collapse at some intermediary floors.

This earthquake created another opportunity to re-assess the engineering practice and improve the design and construction procedures.

Damage to SRC/RC Buildings due to 1995 Kobe Earthquake

HSC Buildings in and around Tokyo

A 120MPa Concrete Bridge (Pedestrian Overpass)
Application of High-Strength and High-Performance Concrete in Seismic Regions

Outline

- High-Strength and High-Performance Concrete in Seismic Regions
- Transition of Number of High-Rise RC buildings
- Evolution of High-Strength Materials
- Transition of Strength of Longitudinal Bars
- Why High-Rise RC Building?

Evolution of High-Strength Materials

Transition of Strength of Longitudinal Bars

Why High-Rise RC Building?

High RC buildings can be constructed with equal period to that of steel buildings. High RC has larger cost merit than those of Steel and SRC buildings.

- Habitability due to High Stiffness,
- Good Sound Insulation,
- Constructionability and Economy

1. 80 stories
2. 70 stories
3. 60 stories
4. 50 stories
5. 40 stories
6. 30 stories
7. 20 stories
8. 10 stories
9. 0 stories

- Bridge (80-150N/mm²)
- Pier (100-150N/mm²)
- RC wall (60-150N/mm²)
- Rock shed (60-75N/mm²)
**Application of High-Strength and High-Performance Concrete in Seismic Regions**

### Outline

1. **Why HSC for Bridge Structures?**
2. **Section and Floor Plan**
3. **Strength of Concrete Core**

#### Why HSC for Bridge Structures?
- Cable stayed bridge
- Extradosed bridge
- Girder structure: Main beam concrete higher than 800N/mm²
- Girder structure: Main beam concrete lower than 800N/mm²

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<th>EQ Damage</th>
<th>High-Strength Fire-Resistant</th>
<th>Self-Compacting High-Durability</th>
<th>Fiber-Reinforced High-Ductility</th>
<th>Concluding Remarks</th>
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#### Section and Floor Plan

**Casting Column Concrete**

**As of May 28 2007**

**Column Section**

#### Strength of Concrete Core

- **Conventional technology**
- **New technology**

**Silica fume cement**

**High-range water reducer**

**High-Strength Fire-Resistant**

**Self-Compacting High-Durability**

**Fiber-Reinforced High-Ductility**

**Concluding Remarks**
Application of High-Strength and High-Performance Concrete in Seismic Regions

Outline
1. Introduction and Summary of High-Strength Concrete
   - High-Strength Concrete
   - Self-Compacting High-Performance Concrete
   - Fiber-Reinforced High-Performance Concrete
   - Concluding Remarks

2. Fire-Resistant Concrete
   - Ordinary High-strength Concrete
   - Steel Fiber-Reinforced Concrete
   - Concluding Remarks

3. Structural Test on HSC and UHSC Columns
   - Test of Column Damper
   - Test of Exterior Column
   - Concluding Remarks

4. Advantages of using self-compacting concrete
   - Shortening the construction period of large-scale structures.
   - Ensuring the filling of concrete into densely reinforced portions where the use of an internal vibrator is impracticable.
   - Reducing the vibration noise during the production of concrete products.
   - Increasing the durability of concrete structures by minimizing the placement-related defects.

   - Self-Compacting Concrete
   - Fiber-Reinforced Concrete
   - Steel Fiber-Reinforced Concrete
   - Concluding Remarks

6. Conclusion
   - Summary of findings
   - Future research directions
   - Acknowledgments
   - References

7. Appendix
   - Additional data and figures
   - Supplementary information

8. Acknowledgments
   - Gratitude to contributors

9. References
   - List of sources cited

10. Index
    - Key terms
    - Figures
    - Tables
Application of High-Strength and High-Performance Concrete in Seismic Regions

Outline

1. High-Durability Concrete

   A 40-story CFT Building

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   Test of Bottom-up Pumping

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2. High-Ductility Concrete

   High-Ductility Concrete (ECC)

   Composition of UFC

   Application of stay-in-place forms to a fierce chloride-laden environment

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   A high-rise RC housing complex using ECC for coupling beams between core walls (41-story and 150m height)

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   Ultra-High-Strength Fiber-Reinforced Concrete

   UFC is an epoch-making high-ductility/high-performance concrete having a compressive strength exceeding 150 N/mm² as well as a high tensile strength exceeding 10 N/mm².

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3. Durability

   Concrete story and 150m height

   Application of High-Durability Concrete in Japan

   K. Yokota et al. Highly Durable Concrete in Japan.

   Keynote Paper, 9THRHCPC Symposium, 4988.55

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   Shotcreting of ECC

   Rehabilitation of a tunnel using ECC

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4. Concluding Remarks
Application of High-Strength and High-Performance Concrete in Seismic Regions

**Sakata Mirai Bridge Using 200MPa UFC**

- **Reference:** Nikken Construction: September 13, 2002
- **Comparison of Girder Section**

**JSCE Recommendations for ECC and UFC**

- Recommendations for Design and Construction of High Performance Fiber Reinforced Concrete
- Recommendations for Design and Construction of Ultra High Strength Fiber Reinforced Concrete Structures (SHS), 2008

**Needs of UFC for Buildings**

- **Social Needs**
  - Higher building
  - Wider living space
  - Smaller member section
  - Longer durability

- **Potential Needs**
  - If a building is free from earthquakes by using seismic isolation, novel design and creation of new space can be possible using UFC.

**Concluding Remarks (1)**

- **High-Strength Concrete (HSC)**
  - HSC up to 120MPa strength has been applied to many civil engineering structures (bridges, tanks, shelter, etc.)
  - HSC up to 150MPa strength has been applied to many high-rise RC buildings, mostly housing complexes.

- Development of higher strength concrete than 120MPa, however, less expensive than 200MPa-UCF, is required.
- Development of high-strength added with high-durability concrete is required on the extension of ordinary concrete.
### Concluding Remarks (2)

**Self-Compacting Concrete (SCC)**

SCC has been applied to many civil engineering structures (tunnels, bridges, underground LNG tanks, etc.) where casting and vibrating concrete is difficult.

SCC has been applied to many CFT buildings and seismic rehabilitation of existing buildings (placing walls and jacketing columns with concrete) where casting and vibrating concrete is difficult.

Comprehensive estimation of the cost by owners considering LCC as well as initial cost will promote the dissemination of SCC.

### Concluding Remarks (3)

**High-Durability Concrete (HDC)**

Durability Enhancement by Innovation in Materials Improvement and Mix Proportioning

Durability Enhancement by Highly-Durable Stay-in-Place Forms.

Design and production of highly durable concrete are strongly requested for realizing sustainability. Though the initial cost is high for HDC, LCC may be decreased.

### Concluding Remarks (4)

**High-Ductility Concrete (ECC)**

ECC has been applied to many civil engineering structures (tunnels, bridges, gravity dams, etc.) where cracks must be kept fine or large ductility is required.

ECC was applied to connecting beams between 3-D shear walls in a high-rise RC building because of its excellent energy absorbing performance.

JSCE published recommendations for “Multiple Fine Crack-type Fiber-Reinforced Cementitious Composite (drafts) in March 2007.

Comprehensive estimation of the cost by owners considering LCC as well as initial cost will promote the dissemination of ECC.

### Concluding Remarks (5)

**High-Ductility Concrete (UFC)**

UFC with 150 MPa or more strength has been applied to bridges where 1) small member thickness, 2) light weight, 3) small beam depth, 4) no reinforcing bars, are required.

UFC has not been applied to main structures in buildings, though R&D studies have been conducted.


Cost estimation by owners considering LCC and preparation of law for special materials will promote the dissemination of UFC for building structures.