JCI Guidelines

Chapters 1 and 2

Takafumi Noguchi
The University of Tokyo
Chapter 1
General

1.1 Scope
1.2 Definitions
1.3 Notation
1.1 Scope

This document provides **standard guidelines** for design, construction and inspection necessary

- to **control thermal cracking** due to heat of hydration of cement as well as autogenous shrinkage in concrete structures, and
- to **prevent DEF cracking** in concrete structures.

Items not covered in the Guidelines shall be in accordance with

- “**Standard Specifications for Concrete Structures 2012**” (Design, and Materials and Construction) published by **JSCE**, or
Chapter 2

Basis of Control and Prevention of Cracking Due to Heat of Hydration of Cement

2.1 Basic Principle
2.2 Target and Index of Thermal Crack Control
2.3 Index of DEF Crack Prevention
2.4 Control and Prevention Procedures
2.1 Basic Principle

- The target of **thermal crack control** shall be set and achieved so as to meet the **performance requirements** of the structures.
- The target of **DEF crack prevention** shall be set and achieved so as to meet the **performance requirements** of the structures.

<table>
<thead>
<tr>
<th>Performance requirements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>Crack usually neglected</td>
</tr>
<tr>
<td><strong>Serviceability</strong></td>
<td>Crack prevented toward airtightness, water-tightness, etc.</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>Crack prevented in extremely corrosive environments</td>
</tr>
<tr>
<td></td>
<td>Crack width controlled within the allowable limit</td>
</tr>
<tr>
<td><strong>Aesthetic</strong></td>
<td>Crack carefully controlled</td>
</tr>
</tbody>
</table>
2.1 Basic Principle

■ Safety
  ○ General
    ◆ Yield strength of tensile reinforcing steel ⇒ Flexural capacity of members
    ◆ Thermal cracking is generally neglected due to little decrease of capacity.
  ○ Exceptions
    ◆ Cracks which change the prerequisites of structural design ⇒ Safety
    ◆ Thermal cracks need to be controlled.

■ Serviceability
  ○ Large influence due to thermal cracking
    ⇒ Leakage of water or air
    ⇒ Decrease of stiffness
    ⇒ Increase of deflection
    ⇒ Change in the vibration characteristics

○ Thermal cracking shall be prevented.
2.1 Basic Principle

- **Durability**
  - Crack width > Limit value
    - $O_2$, $CO_2$, water and $Cl^-$ transported into concrete
    - Acceleration of deterioration in reinforcing steels
  - For structures in extremely corrosive environment
    - Even a very fine crack $\Rightarrow$ Penetration of the deleterious substances
    - Thermal cracking shall be prevented.

- **Aesthetic including damage to third party**
  - Cracking $\Rightarrow$ Causing a sense of insecurity in users and nearby residents
  - Thermal cracking shall be carefully controlled.
2.1 Basic Principle

- **DEF cracks**
  - Concrete expansion: Several %
  - Crack width: 7-10mm
  - High possibility of reinforcement yielding
    - Loss of structural safety
  - Infiltration of water into concrete
    - Increase of crack width
    - New cracking
  - Basic target: Prevention of DEF cracking
  - Conditions for cracking
    - Alkali and SO$_3$
    - High temperature history at early age
    - Continuous contact with water
2.2 Target and Index of Thermal Crack Control

- The target of thermal crack control shall be the prevention of thermal cracking or the control of crack width.

- **Thermal cracking probability** is a reference index for control and verification when seeking to prevent thermal cracking.

- **Crack width** is a reference index for control and verification when allowing thermal cracking.
2.2 Target and Index of Thermal Crack Control

- Concrete structures in which thermal cracking must be prevented
  - Structures in which **airtightness** or **water-tightness** is achieved only by concrete, or
  - Buildings in which thermal cracking would seriously undermine the **aesthetic appearance and value**

- Prohibiting the occurrence of cracks in **all concrete structures**, even if technically possible
  \[ \Rightarrow \text{Excessive cost} \]
2.2 Target and Index of Thermal Crack Control

- Target of control
  - Performance requirements for structures
    - Resistance to water leakage?
    - Effect of cracking on durability? (Intended service life?)
    - Aesthetic?
  - Environmental conditions around structures
    - Extremely corrosive environment?
    - General environment?
- Prevention of crack? Control of crack width?
  - Control of thermal cracking probability
  - Control of crack width
2.2 Target and Index of Thermal Crack Control

Index of thermal crack prevention: **Thermal cracking probability**
Various uncertainties in material properties, surrounding conditions, analytical methods, etc.
⇒ Probabilistic event

![Diagram showing factors affecting thermal cracking probability](image)
2.2 Target and Index of Thermal Crack Control

- **Thermal cracking probability**
  - Expected reliability $\Rightarrow$ Allowable cracking probability
  - Material properties + 3D FE analysis
    $\Rightarrow$ **Thermal cracking index**
  - Actual data on thermal crack occurrence
    $\Rightarrow$ **Thermal cracking probability**

- **Thermal crack width**
  - Experimental data (see Reference Material 25)
    $\Rightarrow$ Recommended equation to predict thermal crack width in relation to thermal cracking index
2.3 Index of DEF Crack Prevention

- The **maximum temperature** in a concrete member is a reference index for control and verification when seeking to prevent DEF cracking.

**Conditions for DEF cracking**
- Temperature history of concrete
- Water supply to concrete
- Alkali content in cement
- SO₃ content in cement

**Even though concrete always exposed to water**
Maximum temperature of concrete < the limit value \(\Rightarrow\) DEF cracking prevented
2.4 Control and Prevention Procedures

The control of thermal cracking and the prevention of DEF cracking shall be performed by setting the control and prevention targets, control and prevention planning, analysis and verification, execution planning, quality control, and inspection, according to the following procedures.

[1] Design: Chapters 2, 3 and 4
[3] Inspection: Chapter 6
[1] Design: Chapters 2, 3 and 4

1. **Basic principle** of control of thermal cracking and prevention of DEF cracking (Chapter 2)
   - Setting of **target** and **index**

2. **Planning** for control and prevention (Chapter 3)
   a. Determine the **limit values** for controlling thermal cracking based on the performance requirements of the structure.
   b. Determine the **maximum concrete temperature** for preventing DEF cracking.
   c. Set the **methods** for control of thermal cracking and prevention of DEF cracking.
   d. Set the **specifications** for materials and mix proportions of concrete, execution procedures, crack control joints, arrangement of reinforcement, etc. for achieving the control target.
[1] Design: Chapters 2, 3 and 4

3. Verification (Chapter 4)
   - Predict the thermal cracking index and the maximum temperature for preventing DEF cracking by an appropriate method, and verify that each of the predicted indices does not exceed the corresponding limit value.
   - This verification can be omitted if the specifications are determined based on sufficient actual results of existing structures where control of thermal cracking and prevention of DEF cracking have been successfully performed.

4. Determination of specifications (Chapter 4)
   - Determine the specifications for the materials and mix proportions of concrete, execution procedures, crack control joints, arrangement of reinforcement, etc., based on the results of verification.

- **Plan** the execution and quality control procedures based on the determined specifications.
- **Execute** concrete production and placement under appropriate execution control according to the execution planning.
- **Confirm** the achievement of control of thermal cracking and prevention of DEF cracking based on the results of quality control.
[3] Inspection: Chapter 6

- **Conduct inspection** to ensure that the targets for controlling thermal cracking and for preventing DEF cracking are achieved for the concrete structure, and **take appropriate measures** if unachieved.
Procedure for thermal cracking control and DEF cracking prevention

[1] Design
[2] Construction works
[3] Inspection
Verification flow for DEF cracking
(3D-FEM carried out)

1. Utilize proven specifications for preventing DEF cracking?
   - Yes
   - No
     - Surface of concrete member in contact with water?
       - Yes
         - Contact continuously?
           - Yes
           - No
         - No
       - No
         - Control target is prevention of thermal cracking?
           - Yes
             - Maximum temperature at the surface layer meets the limit value?
               - Yes
               - No
             - No
           - No
             - Maximum temperature at the central portion meets the limit value?
               - Yes
               - No
             - No
         - No
   - No

2. Planning for control of thermal cracking / prevention of DEF cracking.
3. Determination of design and execution specification.
Verification flow for DEF cracking

(3D-FEM not carried out)
Thank you very much for your kind attention!