ISBN978-4-8189-5011-5

Recommendations for Practice of Thermal Cracking Control of Massive Concrete in Buildings

(2019 Edition)

AIJ-2022

Architectural Institute of Japan

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Issued Jan. 10, 2023
ISBN978-4-8189-5011-5　C3052

Edited and published by Architectural Institute of Japan

FOREWORD

Massive concrete members with large cross-sectional dimensions may crack due to the temperature rise and fall caused by the heat liberation of cement hydration process. This is generally referred to as thermal cracking of mass concrete. Thermal cracks can become penetration cracks, and it is important to take countermeasures against them to ensure durability and prevent leakage.

However, the prevention of thermal cracking in massive concrete are not always easy. This is due to the fact that the mechanism of thermal cracking is extremely complex and cannot be specified in a uniform manner, as the measures to be taken may be completely different depending on the member dimensions, ground conditions, and casting zone.

Therefore, numerical analysis using the finite element method (FEM) and/or other methods is necessary to take appropriate countermeasures. However, the thermal stress analysis software for mass concrete are not available to everyone because they are not necessarily inexpensive and their use is complicated.

Against this background, the Architectural Institute of Japan (AIJ) established and published the "Recommendations for practice of thermal cracking control of massive concrete in buildings " in February 2008, and subsequently revised and published the recommendations in November 2019, reflecting latest findings. This recommendations is English version of the recommendations published in November 2019.

The physical property values shown in this recommendation are averages of the data of Japanese productions. When applied to other countries, the properties of cement, aggregate, and characteristics of concrete production should be appropriately reflected.

The following are some of the features of this recommendation:

1) Both performance design and specification design are presented, and the user can choose either one.
2) The three-dimensional finite element method was used to perform parametric studies under various conditions, and their results were summarized in charts. The charts are applicable to a wide range of members and materials, but certain countermeasure proposals can be obtained without FEM application.
3) As the design concrete strength is increasing, autogenous shrinkage strain is fully incorporated, and countermeasures are presented by taking into account of autogenous shrinkage strain in specification design, performance design, and design with charts.
4) A wide range of cement types are covered, including ordinary Portland cement, low-heat Portland cement, and blended cements.

As described above, this recommendation incorporates the latest findings and is designed to be immediately applicable in practice. It is hoped that this publication will contribute to the reduction of thermal cracking of mass concrete and be of use to researchers and engineers in the field of mass concrete.

November 2022

Architectural Institute of Japan

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Chapter 1 General rules

1.1 Scope of application

a. The recommendations apply to mass concrete in on-site constructed reinforced concrete buildings as well as in buildings constructed other than reinforced concrete.

b. In the recommendations, mass concrete refers to the concrete in the members where the minimum cross section of the member is large and harmful cracks may be caused by temperature rise due to the heat of hydration of cement.

c. In principle, the recommendations apply to concrete with a design strength of 18–36 N/mm^2.

d. Items not included in the recommendations shall be based on “Japanese Architectural Standard Specification JASS 5 Reinforced Concrete Work (hereafter abbreviated as JASS 5)” of the Architectural Institute of Japan or other related recommendations.

1.2 Objectives

a. The aim of the recommendations is to control the occurrence of harmful thermal cracks in mass concrete.

b. The standard for the control of thermal cracks in mass concrete is specified in the recommendations.

1.3 Precautions for application

Countermeasures against cracks in mass concrete must be comprehensive and effective in all fields, from planning and design to materials, mix proportion, and construction. Therefore, the designer, construction supervisor, and constructor should discuss in advance to ensure that the items indicated in the recommendations can be implemented accordingly.

1.4 Terms

The following terms as well as the terms defined in JIS A 0203 (Concrete terminology) and JASS 5 are used in the recommendations:

Mass concrete : Concrete in the members where the minimum cross-section of the member is large and harmful cracks may be caused by temperature rise due to the heat of hydration of cement.

Thermal stress : Stress generated in concrete when the temperature distribution inside a concrete member is not uniform, or when the volume changes following temperature rise or fall is externally restrained significantly.

Internal restraint : Restrain due to the balance of forces in the cross section when the temperature distribution inside a concrete member is not uniform.

External restraint : Restrain that occurs when the volume change of concrete following temperature rise or fall is hindered by external restraints.

Thermal cracks : Cracks caused by thermal stress due to the heat of hydration of cement.

Slab-type members : Generic term for members with one main large flat (dimension), such as a pressure plate (matt slab).

Wall-type members : Generic term for members with wall-like shapes, such as foundation beams and earth pressure walls.

Performance requirement : Various performance requirements for structures and members of buildings.

Limit state : A state that represents the acceptable limit where the structure and its members fulfill the required performance.

Target performance : Performance prescribed as the design goal with an appropriate margin to ensure that the required performance is achieved.

Design value : Target value of crack width or stress strength ratio imposed on structural concrete from the viewpoint of control design for achieving the target performance for structures and members.

Permissible crack width : Width of permissible crack below which deterioration with respect to function and durability of the structure may not occur.

Thermal cracking strength : Tensile stress in concrete corresponding to thermal crack initiation.

Stress–strength ratio : Ratio of thermal stress to thermal cracking strength of concrete.

Chapter 2 Principle for control of thermal cracking

2.1 General principles

a. Structural concrete shall not have thermal cracks that can impede the achievement of the required performance of structures and their members.

b. The performance of the structures and their members included in the recommendations is the leakage resistance and corrosion resistance of steel bars.

c. The designer shall establish appropriate limit states for the thermal crack width of structural concrete based on the performance requirements of the owner and others for the structure and its members.

d. Leakage resistance is evaluated based on the presence or absence of thermal cracks in the structural concrete. The limit state of the leakage resistance is defined as the state in which thermal cracks result in leakage in the structural concrete.

e. Corrosion resistance of reinforcing bars is evaluated by the width of the thermal cracks in the structural concrete. The limit state of corrosion resistance of reinforcing bars is defined as the state in which thermal cracks may promote the corrosion of reinforcing bars owing to the progress of carbonation.

f. To control the thermal cracks such that the structure and its members do not reach the limit state within the specified period, the designer shall set specifications such as the materials, mixtures, and construction methods of concrete via either performance design or specification design, and the constructor shall perform the appropriate construction works based on the specifications.

2.2 Allowable value and design value for thermal cracking control

a. The designer shall establish allowable and design values for the control of thermal cracking of structural concrete via experiments or reliable date documentation based on Section 2.1.

b. The condition of cracks to ensure leakage resistance is that no penetration cracks shall occur, and if controlled by the stress–strength ratio, the design value shall not exceed 0.8.

c. The allowable maximum crack width to ensure the corrosion resistance of reinforcing steel bars in a general environment is 0.4 mm, and if controlled by the stress–strength ratio, the design value shall not exceed 1.3.

Chapter 3 Typical specifications

3.1 General

a. This chapter specifies the basic points to be considered in the design of thermal cracking control for mass concrete.

b. Items not indicated in this chapter shall be determined based on the regulations stated Chapter 4 “Performance Design,” Chapter 5 “Prediction of Stress-strength Ratio by Charts” or Chapter 6 “Specification Design”

3.2 Materials

a. The standard cement should be specified as ordinary, high-early strength, moderate-heat, low-heat, and sulfate-resistant Portland cement, as in JIS R 5210 (Portland cement), or blended cement, based on the regulations of JIS R 5211 (Portland blast-furnace slag cement) and JIS R 5213 (Portland fly ash cement).

b. Chemical admixtures are air-entraining admixtures, water-reducing admixtures, air-entraining water-reducing admixtures, high-performance water-reducing admixtures, high-performance air-entraining water-reducing admixtures, and plasticizers, and the standard should be a delayed type or standard type that conforms to the regulations of JIS A 6204 (Chemical admixtures for concrete) and classified as Class I based on the amount of chloride ions (Cl^-).

c. Appropriate admixtures should be used after a thorough consideration of their effects. Fly ash should be determined from fly ash class II as specified in JIS A 6201 (Fly ash for use in concrete), whereas ground granulated blast-furnace slag should be determined from ground granulated blast-furnace slag 3000 or 4000 as specified in JIS A 6206 (Ground granulated blast-furnace slag for concrete). It is noted that the maximum amounts of ground granulated blast-furnace slag and fly ash to be used are 70% and 30%, respectively, of the cement.

d. The standard expansive material should be specified in JIS A 6202 (Expansive additive for concrete) and shall be used after a thorough examination of its effect.

e. The aggregates shall be in accordance with Section 4 of JASS 5.

3.3 Mixture proportions

a. The mixture proportion of concrete should be determined such that the unit cement content is minimized, and the required concrete quality can be achieved.

b. The material age n (days) to guarantee the strength of structural concrete shall be between 28 and 91 days, with 91 days being the standard.

c. Structural concrete strength is expressed as the compressive strength estimated using a reasonable method based on standard cured specimens.

d. The standard age m (days) for determining the mixture strength is 28 days or more, but not older than the age at which the strength of the structural concrete is guaranteed.