Introduction to the New Recommendation for Design and Construction of Concrete Structures Using FRP

「FRP を用いたコンクリート構造物の設計・施工指針」の紹介

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1. Introduction

Having the advantages of being rust-free, high-strength and lightweight, fiber reinforced polymer (FRP) produced by impregnating carbon, aramid, glass or basalt fibers with resin has attracted attention as alternative reinforcements to steel bars and prestressing steels. The “Recommendation for Design and Construction of Concrete Structures Using Continuous Fiber Reinforcing Materials” was published by the Japan Society of Civil Engineers (JSCE) in 1996. The JSCE’s recommendation was the world’s first set of guidelines stipulating design, construction and test methods for applying FRP to concrete structures. However, it has not been revised and is still used at present. As such, the Japan Prestressed Concrete Institute (JPCI) established the new recommendation (JPCI’s recommendation) in both Japanese and English by incorporating the latest research outcomes on the basis of the JSCE’s recommendation.

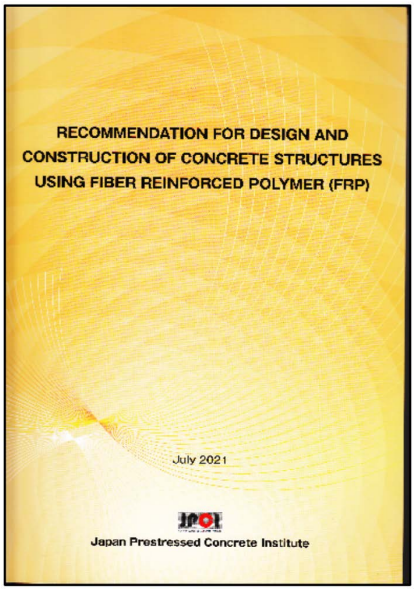

Fig. 1 New Recommendation for Design and Construction of Concrete Structures Using Fiber Reinforced Polymer(FRP)

2. Scope of the Recommendation

The JPCI’s recommendation apply to the design, construction and maintenance of concrete structures and prestressed concrete (PC) structures using FRP as reinforcements or prestressing tendons. The FRP handled in the JPCI’s recommendation is carbon, aramid or basalt fiber rods impregnated with resin.

3. Table of Contents

4. Summaries of Each Chapter

(1) Chapter 1: General Provisions

Chapter 1 includes the scope of application, basic principle of design, requirements for structures, definition of terms, notation, and related standards.

(2) Chapter 2: Basic Points for Design, Construction and Maintenance

Chapter 2 includes the basic concepts of design, construction and maintenance, design service life and performance verification methods.

(3) Chapter 3: Materials

Chapter 3 introduces basic matters related to materials necessary to ensure the required performance of concrete structures, the test methods to set the mechanical characteristics of FRP such as strength, Young's modulus and relaxation rate, and the design values of respective FRP materials.

(4) Chapter 4: Actions and Chapter 5: Performance Verification

Chapter 4 introduces the types and combinations of actions to be set in each limit state and Chapter 5 stipulates the items subject to performance verification and structural analyses to be performed.

(5) Chapter 6: Ultimate Limit State

Chapter 6 describes the methods for verifying the safety of concrete structures using FRP against flexural moment, shear force and torsion in an ultimate limit state. Regarding the ultimate limit state design for flexural moment, it is necessary to determine optimal failure patterns with member factors appropriately set taking into consideration the types of object structures, actions and FRP as well as economic efficiency on the basis of the facts that (1) flexural compressive failure of concrete is likely to cause a significant reduction in economic efficiency because of increased amounts of FRP, (2) FRP failure before concrete is likely to cause abrupt declines in the capacity of members, and (3) the bond property of each type of FRP affects failure patterns. Regarding shear force, the design shear capacity is based on the JSCE's recommendation assuming that strain of shear reinforcement is 0.003 or 0.0035 referring to overseas standards and research outcomes. When strain is 0.003, the calculation results almost satisfy the lower limit value of experimental results.

(6) Chapter 7: Serviceability Limit State

Chapter 7 describes the performance verification methods for the safety of concrete structures using FRP against stress, cracks, displacement, deformation and vibration in a serviceability limit state.

(7) Chapter 8: Fatigue Limit State

Chapter 8 describes the performance verification methods for the safety of concrete structures using FRP in a fatigue limit state. Using FRP as external cables to reinforce existing or new concrete structures requires durability verification through fatigue tests assuming variable stress on tendons at anchorage sections and the confirmation of the fatigue performance at anchorage sections.

(8) Chapter 9: Durability

Chapter 9 introduces water, alkaline and ultraviolet rays as factors generally affecting the durability of FRP. Regarding alkaline, FRP is likely to reduce tensile strength when exposed to alkaline under high temperature for a long time. Therefore, the JPCI's recommendation requires to design concrete structures taking into consideration the retention rate of tensile strength of FRP.

(9) Chapter 11: Structural Details

Chapter 11 describes the structural details such as concrete cover, required amounts of steel materials, arrangement, shapes, anchorage, etc. necessary for the design of concrete structures using FRP as reinforcement or tendons.

5. References

(1) Trial design of PC bridges using FRP rods and its LCC

The JPCI's recommendation introduces the trial design of PC bridges using FRP rods as prestressing tendons. The trial design has been conducted for 1) a PC slab using aramid FRP, 2) a pre-tensioned PC simple slab girder bridge using aramid FRP, 3) a pre-tensioned PC simple slab girder bridge using carbon FRP, and 4) a post-tensioned PC girder bridge using carbon FRP. The trial design results including calculation results of LCCs (Life Cycle Costs) are described.

(2) Quality standards and test methods

The JPCI's recommendation stipulate the quality standards of FRP on the basis of the revision of existing standards and sets the following new FRP test methods:
1) Test Method for Tensile Properties of Bent Portions of FRP;
2) Evaluation Method for Alkali Resistance of FRP; and
3) Test Method for Alkali Resistance of FRP with Respect to Temperature Conditions during Concrete Curing.

(3) Practical data on FRPs

The JPCI's recommendation also summarizes the product specifications, mechanical properties, durability test results, structural details and actual performance of four types of FRPs currently used in construction and shows the lists of dimensions and various characteristic values of these four types of FRPs.