CHAPTER 2 BASICS OF UPGRADING

2.1 General

When upgrading concrete structures with continuous fiber sheets, suitable methods shall be used to verify that the performance requirements for the upgraded structure are adequately maintained. In addition to the feasibility of upgrading work and the ease of maintenance after its completion, economy shall also be considered.

[Commentary]

In general, the performance required for concrete structures during the service life is specified in advance. Nevertheless, the performance level of concrete structures may sometimes decline to a greater degree than expected, due to excessive deterioration caused by changing environmental conditions or by unforeseeable disasters or the like. In other cases, a higher performance level may be required, or new performance criteria had been introduced due to changes in load conditions and purpose of use accompanying the revision of standards. In such cases, the concrete structures are generally upgraded.

Concrete structures are subject to a wide variety of performance requirements, and appropriate techniques are needed to verify these performance requirements. Table C2.1.1 shows some examples of verification items and performance requirements extracted from the Recommendations for Retrofit of Concrete Structures. However, when verifying the performance of upgraded concrete structures, unlike with new structures, suitable verification techniques for upgrading should be employed.

Upgrading using the continuous fiber sheets covered by these recommendations is done by bonding the continuous fiber sheets onto the structure or jacketing the structure with such sheets. Consequently, it is expected not only to improve the load-carrying performance of the concrete structure but to block the intrusion of substances in the surrounding environment that might cause deterioration of concrete. This method can also be applied to prevent spalling of deteriorated concrete, ameliorating the adverse effects on third parties.

However, these features can only be realized with quantitative evaluation methods and appropriate verification techniques. Previous research has empirically demonstrated the improvement of load-carrying performance of upgraded concrete structures, and evaluation methods have also become quantitative to a considerable extent based on the mechanical properties of continuous fibers. Based on these achievements, methods for the quantitative evaluation of how the sheet contributes to improving safety (flexural load-carrying capacity, shear capacity and ductility) and to improving serviceability (restraining flexural deformation and flexural cracking widths) are proposed in these recommendations.

When selecting an upgrading method, whether the upgraded concrete structure will satisfy the specified performance requirements or not should be considered. In addition, economy throughout the entire life cycle, including ease of construction and ease of maintenance and should also be considered. Continuous fiber sheets and strands have major advantages such as they are lightweight, can be placed manually, and can be easily shaped on site to cope with complex shapes. They can also easily accommodate additional upgrading. However, quantitative methods for evaluating these advantages, as in the case of changes over time in the performance of concrete structures after upgrading, have not yet been established. Future research is expected to result in the further utilization of these advantages.

Table C2.1.1 Sample indicies for verifying the performance of concrete structures upgraded with continuous fiber sheets

Performance	Item	Indicies for conventional evaluation methods	Indicies for elaborated evaluation methods
Safety	Failure and collapse	Flexural load-carrying capacity, shear capacity, torsional capacity, fatigue capacity, response displacement, ductility ratio, etc.	Deformation of or damage to structure due to application of anticipated load (evaluation and verification by numerical simulations)
	Rigid body safety	Over-turning moment resistance, sliding resistance, vertical bearing capacity, etc.	
	Fire	Self-extinguishing ability, fire spreading resistance	
Serviceability	Driving comfort/walking comfort	Displacement/deformation, rigidity, smoothness of road surface, level differences, vibration characteristics of structure and foundation, velocity, acceleration, vibration level, sound pressure, etc. transmitted to users and neighbors	Sense on the part of users and neighbors of the structure's response to the application of anticipated load and the effect of the environment (evaluation and verification of the interrelationship between the structure's response and human sensations)
	Vibration resistance		
	Noise resistance		
	Watertightness/ airtightness	Crack width, coefficient of water permeability, coefficient of air permeability, etc.	
	Appearance	Crack width, crack density, size of stained area, density of stains, color of materials used, paint color, etc.	
	Visual safety	Displacement, deformation, crack width, crack density, sheet peeling area, etc.	
Restorability	Restoration time/restoration cost	Failure mode, response displacement, residual displacement, residual crack width, degree of damage to constituent materials, fire-resistance rating of materials, wear strength and impact strength of materials, etc.	Deformation and failure of structure due to application of anticipated load, and decomposition of constituent materials due to environmental actions

2.2 Upgrading process

The upgrading of concrete structures using continuous fiber sheets shall be in accordance with the procedures specified in the Recommendations for Retrofit of Concrete Structures.

[Commentary]

When upgrading concrete structures, the required performance level for the structure is first set up and an appropriate upgrading method is selected to satisfy the

requirements. When the method of using continuous fiber sheets is selected, the process from planning through construction is implemented as shown in the flow chart in Figure C2.2.1.

Specifically, upgrading should be performed using the following procedure.

(1) A plan for the upgrading of existing concrete structures using continuous fiber sheets is drafted covering the steps from detailed inspection through design of the structure, implementation of upgrading work, and maintenance.

(2) A detailed inspection of the structure is performed in accordance with Chapter 5 "Detailed Inspection of Existing Concrete Structures."

(3) Considering the performance of the structure after upgrading, the current condition of the structure and the conditions for construction, the following items are set up: the continuous fiber material (carbon fiber or aramid fiber), fiber mass, number of plies, scope of use, impregnation resin material, smoothing of existing concrete surfaces, other upgrading specifications and the construction method (bonding or jacketing).

(4) The verification is done to confirm that the upgraded structures using continuous fiber sheets will satisfy the performance requirements at all points during the remaining design service life. The method specified in Chapter 6 "Performance Verification for Upgraded Concrete Structures" should be used for the verification. Since the strengthening of some members may alter the failure mode of the entire structure, due consideration should be given not only to the performance of the members to be strengthened but also to that of the entire structure.

(5) After the structure has been verified to satisfy the performance requirements with use of the specifications and the construction method for upgrading, the upgrading work is implemented in accordance with Chapter 7 "Upgrading Work," and after completion maintenance is conducted in accordance with Chapter 9 "Maintenance of Upgraded Concrete Structures."

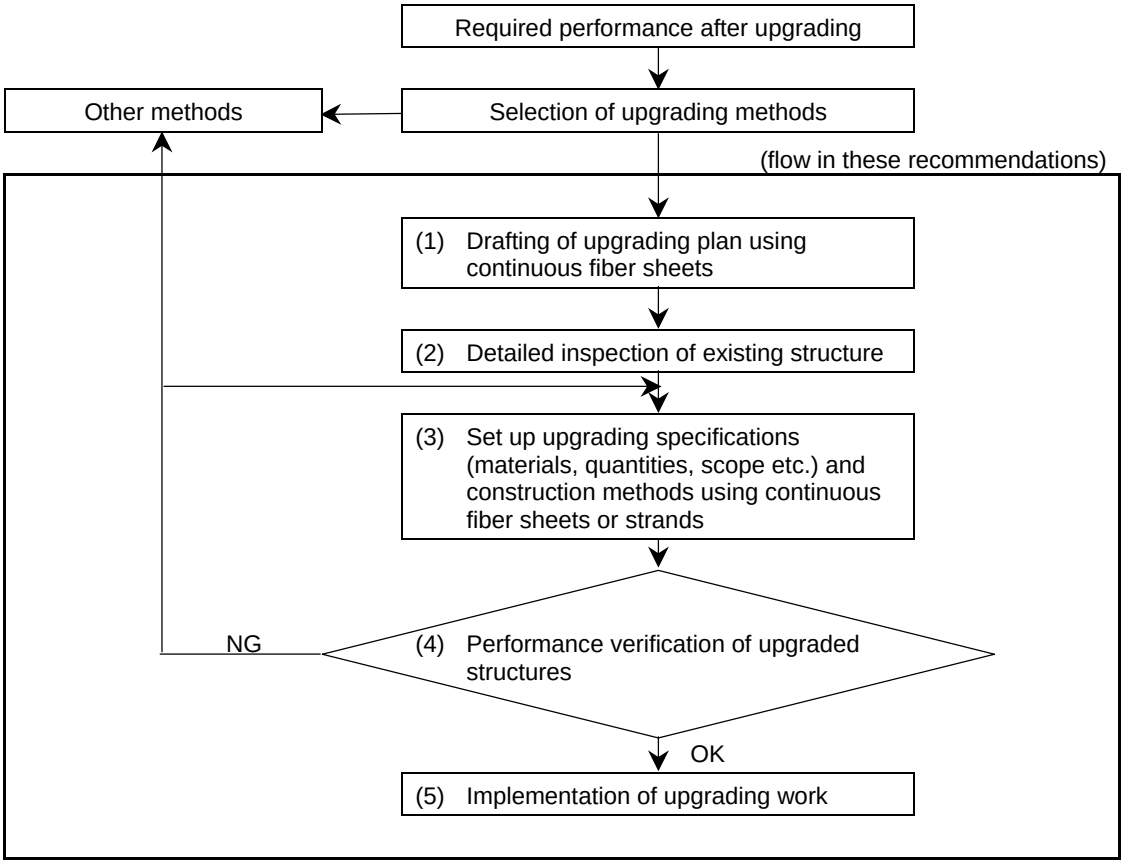

Figure C2.2.1 Upgrading using continuous fiber sheets