Chapter 7 Selection of Retrofitting method

In selecting the retrofitting method, the current status of the existing concrete structure as determined through inspection, the performance of the structure, the performance required of the structure after retrofitting, the conditions for retrofitting construction work, the ease of maintenance, economy and other factors shall be considered.

[Commentary]

At the stage of selecting the retrofitting method, the current status of the existing structure and its performance are known, and the performance required for the structure after retrofitting and the conditions for retrofitting work are given. Factors that should be considered in selecting the method include the effectiveness of the various retrofitting methods with respect to the required performance improvements, the viability of execution of the retrofitting work, the impact of the retrofitting work on the surrounding environment, the ease of maintenance after retrofitting, economy and other factors.

In these (draft) guidelines, practical examples of methods for verifying the performance of retrofitted structures using the external cable method, bonding and jacketing method and overlaying and jacketing method, methods that are often used today and for which technologies are being established, are shown based on existing technologies. In actual retrofitting, a variety of retrofitting technologies (primarily these methods) are generally used together. With the diversification of retrofitting objectives and technical progress, many new methods are expected to be proposed in the future as well.

Table C7.1.1 shows a variety of retrofitting methods, including the three methods covered in these (draft) guidelines, that are designed to improve performance by modifying the dynamic properties of structures. The table classifies these methods by the objective of retrofitting and identifies the members to which they are generally applied and the performance that brings about the retrofitting effect. A summary[4][6-12] of the various retrofitting methods in **Table C7.1.1**, listed by retrofitting objective, is provided below. Since the application of the three methods covered in detail in these (draft) guidelines (external cable method, bonding and jacketing method and overlaying and jacketing method) has most often been limited to beams, columns, slabs and so on, these methods are classified under item 1 "Retrofitting of concrete members."

1. Retrofitting of concrete members

- Continuous fiber reinforced plate bonding construction method:

  Bonding continuous fiber reinforced plates to the surface of the existing structure to restore or improve load-carrying capacity

- Continuous fiber reinforced plate jacketing construction method:

  Jacketing with continuous fiber reinforced plates around the periphery of the existing structure to restore or improve load-carrying capacity and deformation characteristics

- Prestressed concrete jacketing construction method:

  Placing prestressing wires and prestressing stranded steel wires in place of lateral ties around the periphery of existing member sections and using mortar and concrete to bond them in order to reinforce the structure. To increase the restraining effect of the inner concrete, the prestressing steel is generally stressed during placement. This method is sometimes used together with the mortar spraying method and precast panel jacketing method.

- Prestressing introduction (internal cable) construction method:

  Using internal cables for the existing concrete members to provide prestressing and restore or improve the load-carrying capacity of the members.

- Repaving method:

  Replacing some or all of the existing concrete members with new members through the use of precast members or concreting on site to restore or improve load-carrying capacity.

2. Retrofitting as a structural body

- Beam (girder) addition method:

Adding beams between the main girders of the existing reinforced concrete deck to reduce the deck span and restore or improve the load-carrying capacity of the reinforced concrete deck.

- Seismic wall addition method:

  Placing new reinforced concrete walls between existing reinforced concrete rigid-frame bridge piers and bonding them to form a continuous unit in order to restore or improve the load-carrying capacity as a structural body.

- Support point addition method:

  Supporting the intermediate sections of the beams and other existing concrete members with new members to reduce the span of the members in order to restore or improve the load-carrying capacity as a structure.

- Seismic isolation method:

  Using seismic isolation bearings and the like to reduce the seismic energy applied to the structure in order to improve its various performance values during an earthquake.

3. Foundation retrofitting

- Underground wall (beam) addition method:

  Connecting the foundations with cast-in-site diaphragm walls and underground connecting beams to distribute stress and ensure the stability of the entire system.

- Pile/footing addition construction method:

  When pile foundations are damaged or there is residual displacement, adding piles or footings to increase the load-carrying capacity of the foundation.

- Foundation improvement method:

  Improving the ground around the foundation with cement improvement materials to improve the ground bearing capacity and horizontal foundation resistance. Also prevents excessive pore water pressure and liquefaction.

- Steel sheet-pile coffering construction method:

  Placing sheet-piles around the periphery of the footings and bonding them to the footings to improve bearing capacity and horizontal resistance.

- Foundation compacting method:

  When insufficient foundation bearing capacity is a concern due to scouring or the like, using concrete or the like to compact the ground around the foundation in order to restore bearing capacity.

- Ground anchor method:

  When bridge abutments or the like move or tilt laterally as a result of an earthquake, etc., using ground anchors to stabilize the bridge abutments.

4. Bearing retrofitting and prevention of bridge collapse

- Bearing replacement method:

  Replacing existing bearings with new ones to restore or improve bearing function and prevent bridge collapse.

- Bearing retrofitting method:

  Reinforcing the existing bearings themselves to restore or improve bearing function and prevent bridge collapse.

- Shoe/seat retrofitting method:

  Reinforcing or widening the ends of the existing bearings to maintain or restore bearing function and prevent collapse of the superstructure.

- Movement restriction equipment installation method:

  Install new movement restriction equipment on existing members to prevent excessive movement of bearings and main girders and prevent bridge collapse.

- Main girder connection method:

Connecting the adjoining main girders in the bridge axial direction with one another to prevent excessive movement of main girders and prevent bridge collapse. Also used as a method of connecting bridge girders to reduce noise.

- Balance method:

  Using prestressing steel or the like to add additional supports to the supports for existing Gerber hinge girders to prevent sinking of suspended beams and bridge collapse.

- Elasticity restraint method:

  Using external cables to connect the existing superstructure and substructure and introducing suitable stressing force to restrict the movement of the superstructure and prevent bridge collapse.

5. Repair of cracks and missing sections

- Crack fill method:

  Forcing low viscosity resin and ultra-fine cement into the cracks in existing concrete members to seal the cracks.

- Fill method:

  Filling cracks, rock pockets, cavities, peeling and other small-scale missing sections in existing concrete members with resin and mortar to repair sections.

- Section repair method:

  Removing deteriorated or damaged portions of existing concrete members and then restoring these members to their original sectional status using materials with excellent bonding to existing concrete.

6. Ensuring transit routes on bridge road surface

- Pavement repair method:

  Repairing damaged pavement to ensure safety and driving comfort.

- Expansion joint repair method:

  Repairing and replacing damaged expansion joints to ensure safety and driving comfort.

When selecting the retrofitting method, the structure to be retrofitted and the performance to be improved (in other words, the objective of retrofitting) are given. Accordingly, the various conditions should be considered and the ideal retrofitting method selected from the various retrofitting methods listed by retrofitting objective in 1 - 6 above.

For example, seismic retrofitting is generally used for column members and is performed in most cases to improve safety and restorability. In such cases, the primary objective is to increase shear capacity and flexural load-carrying capacity and improve ductility, so in most cases the jacketing method that can satisfy these requirements is used. If retrofitting of column and other members alone is not sufficient, or if an improvement in the performance of the entire bridge structure is desired, in some cases seismic isolation and other retrofitting as a structural body, foundation retrofitting, or various bearing retrofitting methods are combined with this method.

For the retrofitting of bridge decks, it is comparatively common to have as an objective not only improved safety but improved serviceability in terms of driving comfort, vibration resistance and the like. In such cases, the bonding method and overlaying method are often used as methods to control the cracking and deflection that results from flexural fatigue and punching shear fatigue and to reduce the stress level generated in the members; in some cases, the repaving method is also adopted. In cases where the retrofitting of deck members alone is not sufficient, the beam addition method, support point addition method and other retrofitting methods as a structural body are sometimes adopted.

Table S7.1.1 (a) Relationship between performance verification indices and retrofitting methods

Retrofitting Objective	Measure	Specific Construction Method Name *1	Member *2								
			All	Beam	Column	Slab	Wall *3	Bearing	Pile	Foundation	Other
Concrete member retrofitting	Bonding	Steel plate bonding method (bonding method)		●	○	●	○				
		Continuous fiber sheet bonding method (bonding method)		●	○	●	○				
		Continuous fiber retrofitted plate bonding method		○	○	○	○				
	Jacketing	Steel plate jacketing method (jacketing method)			●		○				
		Continuous fiber sheet jacketing method (jacketing method)			●		○				
		Continuous fiber retrofitted plate jacketing method			○						
		Retrofitted concrete jacketing method (jacketing method)			●		○				
		Precast concrete jacketing method			●		○				
		Mortar spray method (jacketing method)			●		○				
		Precast panel jacketing method (jacketing method)			●						
	Introduction of prestressing	External cable method (external cable method)		●	○	○					
		Prestressing introduction (internal cable) method		●	○		○				
	Overlaying for sections	Upper surface overlaying method (overlaying method)		○		●					
		Lower surface overlaying method (overlaying method)		○		●					
		Lower surface spray method (overlaying method)		○		●					
	Member replacement	Repaving method		○	○	●	●				
Retrofitting as a structural body	Addition of beams (girders)	Beam (girder) addition method		●		●					
	Addition of walls	Seismic wall addition method					●				
	Addition of support points	Support point addition method		●		●					
	Seismic isolations	Seismic isolation method	●					●			
Foundation retrofitting	Addition of walls and beams	Underground wall (beam) addition method		○			○				●
	Addition of piles and footing	Pile (footing) addition method							●		●
		Foundation improvement method								●	●
		Steel sheet-pile coffering method								●	●
	Improvement of foundation	Foundation compacting method								●	●
	Ground anchors	Ground anchor method					○				●
Bearing retrofitting and prevention of bridge collapse	Replacement of bearings (including seismic isolations)	Bearing replacement method	●					●			
	Retrofitting of bearings themselves	Bearing retrofitting method						●			
	Retrofitting of bearings and bridge seats	Shoe/seat retrofitting method		○	○			●			
	Movement restrictions	Movement restriction equipment installation method		○	○			●			
	Shift to continuous girders	Main girder connection method		●				●			
	Gerber girders	Balance method		●				●			
	External cables	Elasticity restraint method		●							
Repair of cracks and missing sections	Injection	Crack fill method		●	●	●					
	Fill	Fill method		●	●	●					
	Repair	Section repair method		●	●	●					
Ensuring transit routes on bridge road surface	Repairs to bridge surface	Pavement repair method									●
		Expansion joint repair method									●

Notes *1 Parentheses after method names indicate correspondence with method names noted in these (draft) guidelines
*2 ●: Used comparatively often ○: Use is thought to be possible
*3 Including wall-type bridge piers
*4 ●: Thought to be very effective ○: Somewhat effective but effect is thought to be comparatively minor (indirect)
*5 Effective primarily for punching shear

Table S7.1.1 (b) Relationship between performance verification indices and retrofitting methods

Retrofitting Objective	Measure	Specific Construction Method Name *1	Performance Verification Index *4										
			Safety							Serviceability			Restorability
			Axial force	Bending	Shear	Torsion	Fatigue	Rigid body stability	Ductility	Crack width/density	Deflection/ displacement	Other	
Concrete member retrofitting	Bonding	Steel plate bonding method (bonding method)	●	●	●	●	●			●	●		
	Jacketing	Continuous fiber sheet bonding method (bonding method)	○	●	●	●	●			●	○		
		Continuous fiber retrofitted plate bonding method	○	●	●	●	●			●	○		
		Steel plate jacketing method (jacketing method)	●	●	●	●			●	●	●		●
		Continuous fiber sheet jacketing method (jacketing method)	●	●	●	●			●	○	○		●
		Continuous fiber retrofitted plate jacketing method	●	●	●	●			○	○	○		○
		Retrofitted concrete jacketing method (jacketing method)	●	●	●	●			●	●	●		●
		Precast concrete jacketing method	●	●	●	●			●	●	●		●
		Mortar spray method (jacketing method)	●	●	●	●			●	●	●		●
		Precast panel jacketing method (jacketing method)	●	●	●	●			●	●	●		●
	Introduction of prestressing	External cable method (external cable method)	○	●	●	●	●			●	●		
		Prestressing introduction (internal cable) method	○	●	●	●	●		○	●	●		
	Overlaying for sections	Upper surface overlaying method (overlaying method)	○	●	●*5	●	●			●	●		
		Lower surface overlaying method (overlaying method)	○	●	○*5	●	●			●	●		
		Lower surface spray method (overlaying method)	○	●	○*5	●	●			●	●		
	Member replacement	Repaving method	●	●	●	●	●		○	●	●		○
Retrofitting as a structural body	Addition of beams (girders)	Beam (girder) addition method		●	●	●	●			●	●		
	Addition of walls	Seismic wall addition method		●	●	●					●		
	Addition of support points	Support point addition method		●	●	●					●		
	Seismic isolations	Seismic isolation method		●	●	●					●		
Foundation retrofitting	Addition of walls and beams	Underground wall (beam) addition method	○	●	●	●		●		○	○		
	Addition of piles and footing	Pile (footing) addition method	○	●	●	●		●		○	○		
		Foundation improvement method						●			○		
		Steel sheet-pile cofferdam method						●			○		
	Improvement of foundation	Foundation compacting method						●			○		
	Ground anchors	Ground anchor method						●			○		
Bearing retrofitting and prevention of bridge collapse	Replacement of bearings (including seismic isolations)	Bearing replacement method									○	●	○
	Retrofitting of bearings themselves	Bearing retrofitting method									○	●	○
	Retrofitting of bearings and bridge seats	Shoe/seat retrofitting method									○	●	○
	Movement restrictions	Movement restriction equipment installation method									○	●	○
	Shift to continuous girders	Main girder connection method									○	●	○
	Gerber girders	Balance method									○	●	
	External cables	Elasticity restraint method									○	●	
Repair of cracks and missing sections	Injection	Crack fill method			○	○	○			●	○	●	
	Fill	Fill method	○	○	○	○	○			●	○	●	
	Repair	Section repair method	○	○	○	○	○			●		●	
Ensuring transit routes on bridge road surface	Repairs to bridge surface	Pavement repair method										●	
		Expansion joint repair method										●	

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