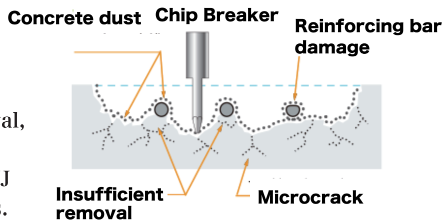
Repair Measures for Existing Bridges

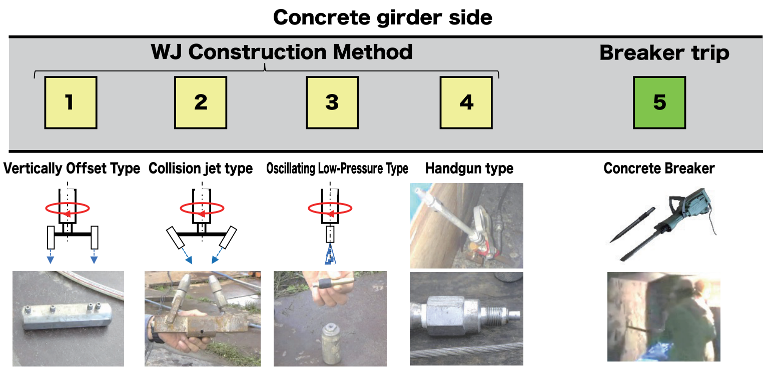
Restoration of Deteriorated Concrete Gelber Bridge
•Adoption of Chipping Technology Using the WJ Method
•Concept of Cross-Section Repair Work

Concrete structures in natural environments deteriorate over time due to neutralization, reinforcement corrosion and concrete spalling caused by de-icing agent application, and concrete weakening from freeze-thaw damage. Consequently, cross-section repair measures involving the removal of deteriorated concrete are frequently implemented. While concrete removal typically employs breakers or pick hammers, this often results in insufficient removal, rebar damage, and microcracks, hindering the integration of new and old concrete after sectional repair. This section presents a case study where the water jet method (hereafter, WJ method) was used to remove deteriorated concrete and implement sectional repair measures.

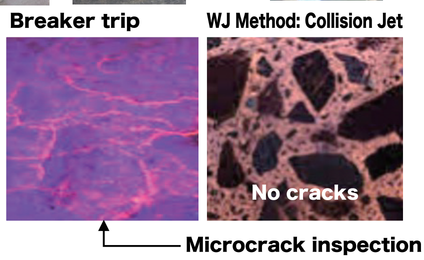


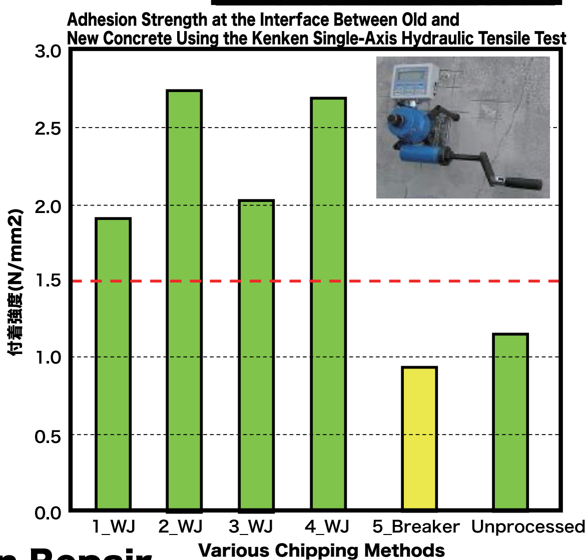
Application of Chipping Technology Using the WJ Method

At Josei, we are verifying the applicability of WJ selectivity (reliable removal of deteriorated sections) using actual structures, alongside evaluating the adverse effects



At that time, we also confirmed the specifications of the WJ method suitable for chipping (setting the nozzle spray angle). For five deteriorated concrete girder sides (see above diagram), we performed chipping using the WJ method with four types of nozzles and a breaker (see upper right video). After chipping, cores were sampled and examined usingluorescent penetrant testing to determine he presence and condition of microcracks. (See video and photo on the right) Microcracks were clearly visible in the breaker section core, but none were observed in the WJ method section core. Results of bond strength tests at the new/old concrete interface using the Kenken single-axis hydraulic tensile testing machine (see right diagram) show that the WJ method consistently meets the bond strength standard of 1.5 N/mm² or higher. However, the breaker section exhibits low bond strength, failing to meet even the untreated control value.





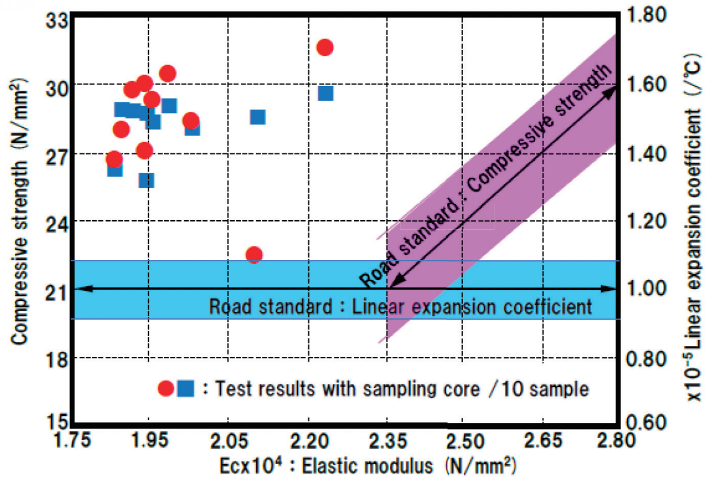
Selection of Materials for Cross-Section Repair

When performing sectional repairs on existing concrete structures using concrete-based materials, there are critical points to consider. It is extremely important to know the ‘elastic modulus’ and ‘linear expansion coefficient’ of the host concrete structure. The elastic modulus is “one indicator representing the stiffness of a material.” A higher elastic modulus means the member is stiffer, while a lower elastic modulus indicates the member is softer. The linear expansion coefficient indicates the rate at which the length or volume of a member expands per unit temperature increase, also known as the thermal expansion coefficient.

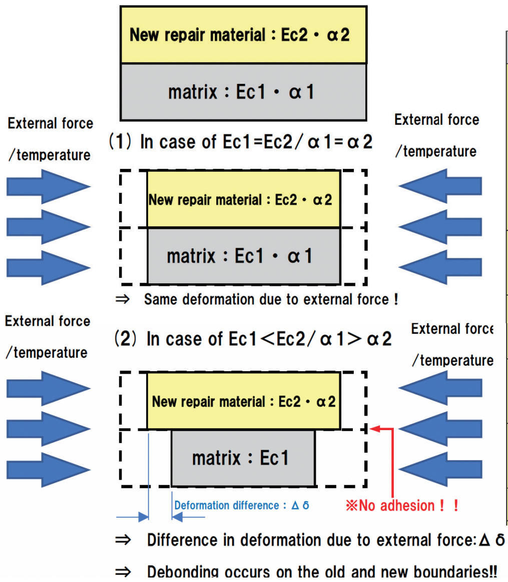
During cross-section repairs, compressive strength tests are conducted as part of the survey of existing concrete structures. Based on these results, it is common practice to estimate the above elastic modulus and select materials accordingly. However, existing concrete structures that have been in service for a long time since completion are subject to deterioration due to natural environmental effects. It is also possible that the distribution of appropriate aggregates, etc., is not stable. The concrete bridge under consideration in this study has been in service for 85 years since completion. The relationship between the compressive strength and the elastic modulus and linear expansion coefficient obtained from cores taken from the main girders is shown in the figure on the right. Compressive strength: σck is concentrated between 27 and 30 N/mm², leading to an estimated elastic modulus: Ec of 2.65 to 2.80 x 10^4 N/mm² (■ range). However, test results showed a significant tendency for values to fall substantially lower, between 1.85 and 2.05 x 10^4 N/mm². Furthermore, while the linear expansion coefficient is specified in the road standards as approximately α =1.00×10⌧5/°C (■ range), the actual values were significantly higher at 1.40 to 1.60/°C.

Mortar Spray Application Conditions Concrete Properties in the Road Bridge Specifications
N/mm2

Design Basis Strength	21	24	27	30	40	50
Young's modulus	$2.35x10^4$	$2.50x10^4$	$2.65x10^4$	$2.80x10^4$	$3.10x10^4$	$3.30x10^4$
Linear Expansion Coefficient	$10x10^{-6}$/℃					



Historical structures often lack documentation detailing their original design specifications, and their physical properties may have significantly changed due to environmental influences. If repair materials are selected without understanding this condition, it is highly probable that bond failure will occur at the interface between the old and new materials, as shown in the lower left diagram (2).



Comparison of physical properties of cross-section restoration materials (Wet spray polymer cement mortar)

Name	Denka Spread Ace	Refre G shot	U-Repair shot
Summary			
Adhesion to concrete (N/mm²)	2.30>1.50	2.70>1.50	2.40>1.50
Elastic modulus (N/mm²)	$1.98x10^4$	$1.92x10^4$	$2.18x10^4$
Linear expansion coefficient (/℃)	$0.91x10^{-5}$	$1.52x10^{-5}$	$1.30 x10^{-5}$
Neutralization resistance	1/5 of ordinary concrete	0.00mm/28day	0.98mm/ Week
遮塩性 (cm²/day)	$2.33x10^{-4}$	$2.55x10^{-4}$	$2.33x10^{-3}$
圧縮強度 (N/mm²)	42.9	41.3	43.7

Based on the above, we selected Refle G Shot as the material for the wet-sprayed polymer cement mortar shown in the table above, as it most closely matches the physical properties of the concrete bridge sections requiring actual cross-section repair. The reasons for using sprayed material are that it eliminates the need for formwork and allows for a final trowel finish that conforms to curved shapes. The actual mortar spraying operation is shown in the video on the right. By adopting the WJ method for removal, microcracking in the existing concrete was prevented. After evaluating the existing concrete's elastic modulus and linear elastic modulus, selecting a section repair material of the same type eliminated concerns about bond failure at the interface between new and old concrete. This ensured the structure's load-bearing capacity could be maintained.

Currently, a monitoring system is being implemented for concrete bridges that have undergone cross-section repair measures to track the future progression of deterioration over time (see left video). This system focuses on the principle of current changes associated with steel corrosion and plays a role in verifying the effectiveness of repairs.