Rapid Reconstruction of the Superstructure of a Bridge Swept Away by Torrential Rainfall in July 2018
— Disaster Recovery Works between the Shingu and Otoyo Interchanges —

平成30年７月豪雨により流出した橋梁上部工の復旧実績
― 新宮 IC ～大豊 IC 間災害復旧工事 ―



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Synopsis
In July 2018, torrential rain fell throughout Japan, but especially in the western part of the country. From July 3 to 8, total rainfall of 1,352 mm and maximum hourly rainfall of 88.5 mm were observed at the Sasagamine South Observation Station between the Shingu and Otoyo interchanges on the Kochi Expressway. This torrential rain triggered a major disaster on July 7, 2018, when a hillside slope collapsed in the Kamimyo District of Otoyo Town, Kochi Prefecture, sweeping away the superstructure of the 63.5-m-long Tajikawa Bridge on the northbound side of the Kochi Expressway (**Figs. 1**, **2**, **3**). The Kochi Expressway is a transportation and logistics lifeline connecting the four prefectures on the island of Shikoku to Japan's main island of Honshu. Thus, it was essential to reconstruct the expressway to four lanes as soon as possible. This paper outlines how the swept away bridge was reconstructed in the shortest possible time to minimize the economic impact.

Structural Data
Structure: 3-span pretensioned prestressed concrete hollow slab bridge
Bridge Length: 63.5 m
Span: 20.2 m + 20.4 m + 20.2 m
Width: 9.9 m
Owner: West Nippon Expressway Co., Ltd.
Designer: West Nippon Expressway Consultants Co., Ltd.
Contractor: KAJIMA Co., Ltd.
Construction Period: July. 2018 - Mar. 2020
Location: Kochi, Japan

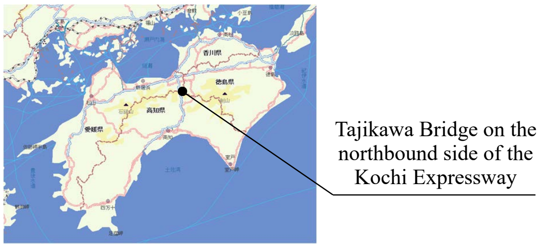


Fig. 1 Location map

Fig. 2 Photograph of the destructive landslide on the hillside (taken July 7, 2018)

Fig. 3 Damage to the northbound Tajikawa Bridge

Fig. 4 The collapsed superstructure buried under the landslide

1. Damage to the Tajikawa Bridge

In the predawn hours of July 7, 2018, the superstructure of the 63.5-m Tajikawa Bridge on the northbound side of the Kochi Expressway between the Shingu and Otoyo interchanges was swept away by a landslide that started outside of the expressway property. The expressway had been closed because of the rainfall from 18:30 of the previous day; no expressway users were harmed. The collapsed area stretched roughly 320 m from the top to bottom of the hillside and was roughly 90 m in width. The estimated volume of collapsed soil was roughly 45,000 m^3. The landslide swept the superstructure of the northbound Tajikawa Bridge down the hillside into the Tachikawa River, a Class A river (**Fig. 4**). Notably, the section of the expressway where the disaster occurred comprises separate northbound and southbound structures; two-way traffic control was implemented on the undamaged southbound side to allow passage in both directions.

2. Evaluation of Substructure Soundness

Visual inspections of the remaining bridge substructure (**Fig. 5**) revealed partial damage at the corners and damage to the bridge accessories, but no significant cracks indicative of structural deformation. Therefore, the reutilization of the substructure was carefully investigated by taking detailed field measurements, and conducting an analytical study to simulate the relationship between the stress history and ultimate strength of the substructure under landslide conditions.

(1) Field Measurements

The heights of substructures and distances between them were measured and compared to as-built drawings and design values; no displacement resulting from the landslide was observed. Seismic prospecting was also conducted, revealing that elastic waves propagated from the top of piers and abutments to the tips of piles and that there was no major damage indicative of the destruction of piers, abutments, or piles.

(2) Analytical Study

The estimated vertical and horizontal loads that would have acted on the collapsed superstructure during the landslide were used to calculate the induced stress in

Fig. 5 Remaining substructure of the northbound Tajikawa Bridge

the substructure. The evaluation confirmed that the piers, abutments, and piles were within their allowable stress values under the conditions in all stress histories to a certain degree.

Given the results of the aforementioned evaluation and analytical study, the decision was made to reutilize the remaining substructure as the substructure of the bridge to be reconstructed after performing partial repairs and replacing the bridge accessories.

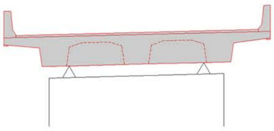
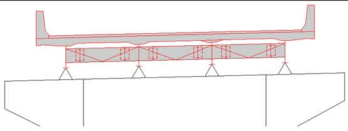
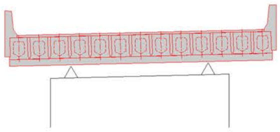
3. Selecting the Structure Type for the Bridge to Be Reconstructed

The following three structure types were compared and considered for the superstructure to be reconstructed.

- Three main girder partially prestressed concrete (PPC) bridge (same as the previous bridge)
- Multi-girder steel bridge
- Precast pretensioned hollow girder bridge

Table-1 shows a comparison of the bridge types. The previous bridge was a 3-span continuous bridge with 3 PPC main girders cast in place. To reconstruct the bridge using this structure type, it would be necessary to install falsework under the viaduct, where collapsed soil from the landslide had accumulated. Removing the soil, grading the site, and constructing the foundations for the falsework was expected to take a great deal of time and pose substantial safety risks.

Table-1 Comparison of structure types for the bridge to be reconstructed

	Three main girder PPC bridge	Multi-girder steel bridge	Precast pretensioned hollow girder bridge
Cross-sectional diagram			
Structural properties	・Reconstruction to the original structure type. ・Original design can be used again; no need for redesign. ・Main girder unit weight : 132.5 kN/m	・Uneconomical cross-section: Limited girder height results in a design with a large amount of thick steel plates. ・Structural modifications required around piers and bearings. ・Main girder unit weight : 73.4 kN/m	・Since precast girders are erected in the form of simply supported girders and connected at intermediate supports in the later stage of the construction, continuous connection can be designed as RC structure with a reasonable amount of rebar, only considering the negative bending moment caused by the live load. ・Main girder unit weight : 123.9 kN/m
Workability (construction schedule)	Cast-in-place falsework is required; time is required for restoring/grading the slope under the viaduct.	Considerable time is required to arrange the many steel plate rolls because of girder height restrictions.	Presents the option of manufacturing in a factory and transporting to the site, resulting in a shorter construction schedule than casting in place.
Evaluation	++	+	+++

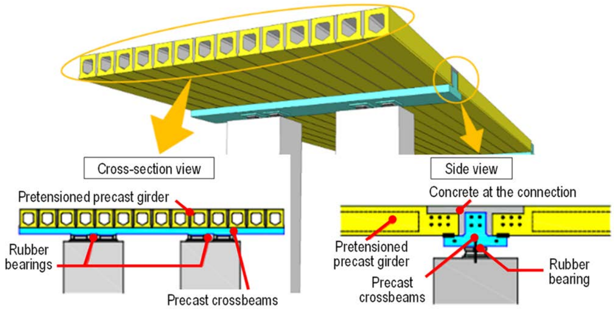


Fig. 6 SCBR construction method

Although the multi-girder steel bridge presented the option of manufacturing the superstructure in a factory rather than casting it in place, reutilizing the existing substructure would limit the height of the girders, resulting in a design with a large amount tonnage of thick steel plates; procuring the materials was expected to take a long time. Furthermore, this type would necessitate structural modifications to the substructure and bearings, which would be challenging in terms of scheduling.

In light of the above, the decision was made to use a precast pretensioned hollow girder bridge with the aim of reconstructing the bridge in the shortest possible time. Selecting a precast superstruc ture presented the option of manufacturing it in a factory while simultaneously repairing the substructure, resulting in a shorter construction schedule. This structure type also involved a lower risk of delays because there is substantially less onsite work than the cast-in-place method. Additionally, the Smart Connected Bridge (SCBR) method was adopted because it would allow the superstructure to be composed of precast components without modifying the existing substructure (**Fig. 6**). In the SCBR method, L- shaped and inverted T-shaped precast crossbeams (**Fig. 7**) are supported by a single bearing line on the abutments and piers, allowing precast girders to be erected and connected in the form of simply supported girders on top of those crossbeams. This eliminates the need to increase the number of bearings to be installed and to widen the piers at the top to support precast girders, offering advantages in terms of shortening the construction schedule.

Fig. 7 Precast crossbeams (top: for abutments; bottom: for piers)

4. Bridge Reconstruction Work

(1) Preparation

Bridge reconstruction work was performed at the bottom of a collapsed slope, and it was necessary to carry out soil removal work at the top of the slope simultaneously. Thus, there was a risk of falling rocks causing an accident. To mitigate the risk and ensure safety, temporary rockfall protection comprising steel H-piles and steel sheet piles was installed between the top and bottom of the slope. Given the possibility of another major landslide during the work, slope conditions were monitored using borehole inclinometers and water gauges installed at various locations on the hillside as well as webcams as the work was carried out.

Fig. 8 Installation of precast main girder

Fig. 9 View of the superstructure after reconstruction

Table-2 Construction schedule

	2018						2019						
	7	8	9	10	11	12	1	2	3	4	5	6	7
	▼2018.7.7 Disaster											2019.7.8 Reconstruction▼	
Preparatory work	Installation of measuring equipment , removal of collapsed soil and sand , installation of rockfall protection												
Substructure repair							Substructure repair						
Superstructure restoration		Detailed design , arrangement of materials											
							Improved fabrication of precast girder						
								Precast girder erection					
										Infilled concrete			
										Wall balustrade , attachment			
												Pavement	

(2) Substructure Repair

In areas where corners and other parts were damaged, a water jet chipping was used to remove the outer layers of concrete. Damaged rebar was cut and then restored with enclosed-arc-welded joints. Additionally, nearly all bridge accessories (e.g., bearings, expansion joints, inspection catwalks) were replaced.

(3) Superstructure Erection

Crane erection was possible for the A2–P2 span; therefore, a 200-ton crane was used to erect the span. The other spans were erected with launching girder (**Fig. 8**). Consequently, the construction schedule was shortened by roughly 2 months compared with that of the previous structure type (**Fig. 9**). The construction schedule is shown in **Table-2**.

5. Conclusion

The superstructure of the Tajikawa Bridge was swept away by a destructive landslide that started outside of expressway pr operty and was triggered by torrential rainfall from a weather front and a typhoon. Although it was projected that quite some time would be needed to reconstruct the superstructure, the decision to reutilize the substructure and adopt precast pretensioned hollow girders made it possible to complete the work and reconstruct the original four lanes of traffic roughly 1 year after the disaster struck on July 7, 2018 (**Fig. 10**).

Fig. 10 Panoramic view of the completed recovery works (taken in August 2021)

概　要

2018年７月，西日本を中心に全国的に広い範囲で大雨となり，高知自動車道 新宮 IC ～大豊 IC 間の笹ヶ峰観測所では，７月３日から７月８日までの総降雨量1,352mm，時間最大雨量88.5mm が観測された。この豪雨の影響により2018年７月７日，高知県長岡郡大豊町上名の山腹斜面の土砂が崩落し，高知自動車道　立川橋上り線の橋梁上部工（橋長63.5m）が流される大規模な災害が発生した。復旧橋梁の構造形式は，最も短工期で復旧が可能な形式として，下部工の構造変更が不要な SCBR 工法を用いたプレキャストプレテンホロー桁橋が選定された。橋梁復旧工事は，主桁のプレキャスト化によって現場作業を大きく低減したことで計画通りに進捗し，災害発生から約１年で４車線復旧を完了させることができた。