※Josei Repair Record; Record ③-1

Temperature Stress Management During Concrete Placement

Construction Management for Seismic Reinforcement Work on Concrete Bridge Piers Damaged by the Kumamoto Earthquake

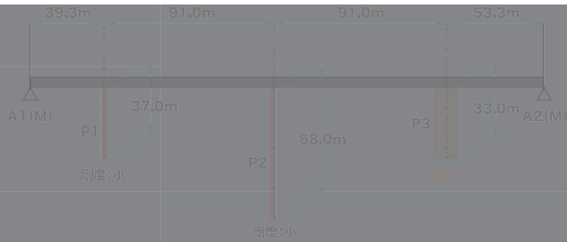
In 2016, the Aso Choyo Bridge sustained significant damage due to the Kumamoto Earthquake. At Josei, to prevent further damage to the earthquake-affected bridge piers during seismic reinforcement work and to evaluate safety during construction in the event of aftershocks, we conducted prior verification through analysis and formulated a management plan. On-site measurement and management were implemented using wireless fiber optic sensors.

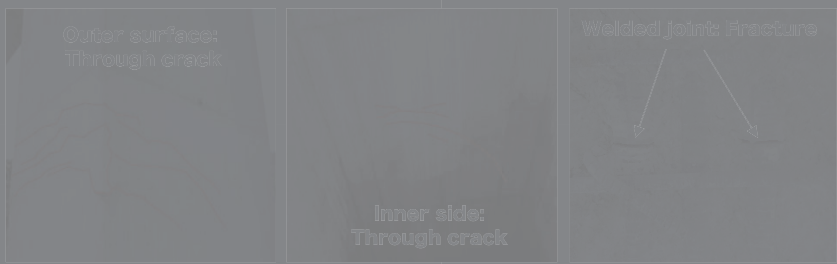
P3 Pier Damage Status and Seismic Reinforcement Measures

The Aso Choyo Bridge is a four-span continuous PC box girder bridge with high piers:

- ·P1 pier height: 37.0m
- ·P2 pier height: 68.0m ·P3 pier height: 33.0m

Due to the high stiffness of Pier P3, damage was concentrated in the form of through-cracking and fractures at the welded joints of the main reinforcement (see photo below right). As this pier has a hollow section, concrete was filled into the pier's hollow interior to reliably restore its stiffness, thereby recovering the sectional rigidity that had been reduced by the damage.

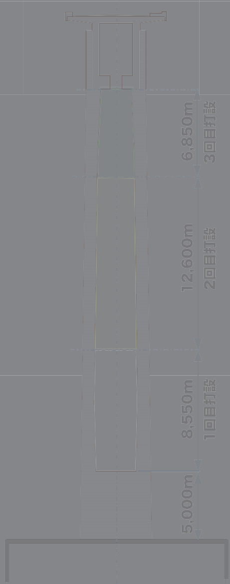




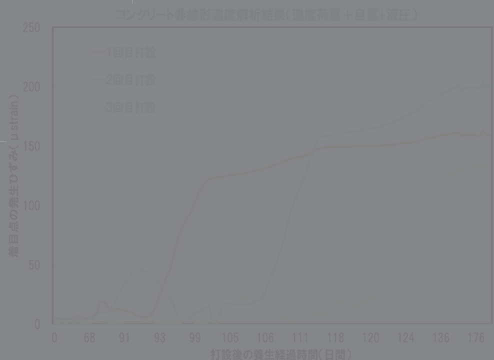
【P3橋脚貫通ひび割れ】 【主鉄筋継手部圧接箇所の破断】

Effects of Temperature Stress During Concrete Placement (Evaluation of Effects Due to Hydration Heat Reactions via Temperature Analysis)

Concerns regarding concrete placement included: ① bulging due to the concrete's own weight and liquid pressure, and ② expansion of the pier structure caused by hydration heat reactions during placement and curing. Therefore, to establish judgment (control) criteria during construction, nonlinear temperature analysis of the concrete (hydration heat model: JCI2008) was performed using FEM analysis.

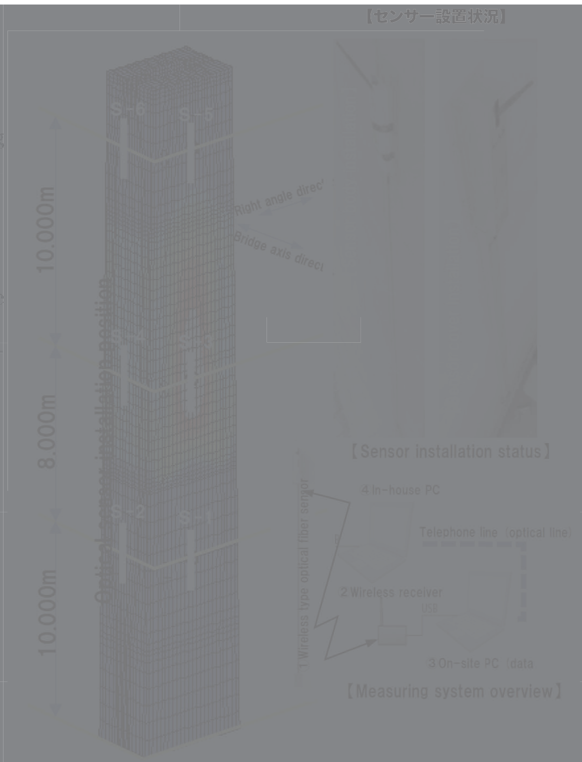


The analysis conditions were set as follows: three pours of high-flow concrete with a compressive strength of $\sigma ck=24\ N/mm^2$, a pour interval of two weeks, and an initial pour temperature of approximately 16°C, assuming April conditions for the region. As a result, the maximum strain developed was $\varepsilon=135.6$ to 204.2 μstrain, which was suppressed to below 25% of the allowable value.

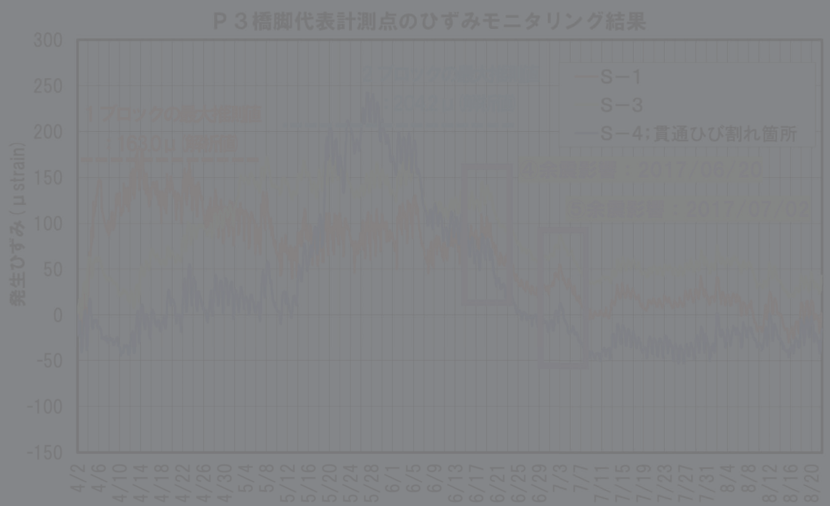


Implementation of Monitoring Management During Construction Using Wireless Fiber Optic Sensors

The previous nonlinear temperature analysis of concrete did not consider earthquake effects in its analysis conditions, leaving the actual behavior during construction unclear. Furthermore, immediately after the earthquake, large aftershocks occurred frequently, making the safety verification of structures under construction a critical factor. Considering these points, we decided to monitor the strain fluctuations occurring in the bridge pier structure during high-flowability concrete placement using optical sensors.
The measurement system used this time employs optical fiber sensors (right photo/figure) that are battery-powered for standalone operation and support wireless multi-hop communication. Consequently, no on-site power supply is required, eliminating the need for cumbersome wiring planning. Furthermore, it does not interfere with the upcoming construction work. Data management utilizes WiFi, enabling remote operation for construction management monitoring.
For the high-flowability concrete placement steps, prioritizing safety, we placed one-third of the total volume during the first pour (equivalent to the first pour in the analysis). Subsequently, we performed 16 additional pours at 1,200-meter intervals, totaling 17 pours to completely fill the interior of the hollow bridge pier.
The figure below shows the strain monitoring trend for representative measurement positions.



The selected measurement locations are the 'S-1 Sensor' with a high per-pour volume, the 'S-3 Sensor' located at the center of the pier, and the 'S-4 Sensor' where a through crack was confirmed. As a result, strain values greater than the analysis value of 204.2μ were measured at the S-4 sensor, the location of the through crack. However, a convergence trend was observed over time, enabling the planned management of the high-flowability concrete placement without issue.



【7 aftershock levels that occurred during the construction】

	1最大発生加速度 (gal)	2標準加速度 (gal)	設計水平震度：kh (1／2)
①2017/05/04 (14:22:28)	３３．８ 益城観測所	９８０	０．０３４
②2017/06/07 (18:20:40)	５．６ 一の宮観測所	９８０	０．００６
③2017/06/18 (22:34:08)	９．３ 高森観測所	９８０	０．００９
④2017/06/20 (23:27:56)	８１．０ 高森観測所	９８０	０．０８３
⑤2017/07/02 (00:58:27)	１５７．８ 高森観測所	９８０	０．１６１
⑥2017/07/07 (04:06:09)	４１．７ 一の宮観測所	９８０	０．０４３
⑦2017/08/08 (21:27:58)	３７．６ 益城観測所	９８０	０．０３８

Impact of Aftershocks During Construction (Safety Management Through Monitoring)

The table on the left shows seven aftershock levels recorded at the seismic observatory near the bridge during the construction period. When converted to design horizontal seismic intensity, all values were kh < 0.20, falling below the standard design horizontal seismic intensity under the Seismic Intensity Method.
The sections in the monitoring results above show the strain trends for the larger aftershocks: ④ June 20 and ⑤ July 2. After the earthquakes, a localized increase in strain was observed. However, this trend converged over time (roughly 4 days), allowing construction to proceed without interruption.
Thus, at Kamiharu, we can comprehensively implement analysis, establish evaluation criteria, and manage the entire construction process. We are constantly committed to ensuring construction reliability and safety