MITIGATION OF EARLY AGE TRANSVERSE CRACKING IN DURABLE RC DECK SLAB ON MULTIPLE SPAN STEEL BOX GIRDER

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1. INTRODUCTION

In Tohoku region of Japan, owing to the complex actions of cold and snowy environment such as freezing and thawing, chloride attack mainly from deicing agent, ASR, cracking, fatigue and so on, a highly durable concrete design accounting for protection countermeasures including low water-to-cement ratio, blast furnace slag or fly ash, expansive additive, anti-corrosion rebar, increased entrained air (around 6% of air content), and sufficient curing has been applied to many bridges to ensure the durability of RC deck slab. However, various investigations have been pointing out that multiple span steel box girders showed a higher risk of early age transverse cracking in RC deck slabs due to the volume change coupled with external restraint condition of composite action of deck slab and girder, stepwise construction procedures and penetration of vertical cracks from the joints in parapet walls. The purpose of this study is to verify the proposed countermeasures for mitigating early age transverse cracking in durable RC deck slab on multiple span steel box girder Fudaigawa bridge considering the application of increased expansive additive with 25kg/m^3, the new joint system to control vertical cracking in parapet walls and the sophisticated stepwise construction method. Full-scale numerical simulation was conducted and the effects of countermeasures were verified by investigation in actual Fudaigawa bridge.

2. METHODOLOGY

2.1 Laboratory and structural investigations

Three leveled experiments were conducted to verify the effectiveness of applied countermeasures to Fudaigawa bridge and to obtain necessary information for FEM modeling and verifications. In material level laboratory tests, the adiabatic temperature rise, the compressive strength development and the coefficient of thermal expansion were obtained. As for member level laboratory tests, the cylindrical expansive specimen according to JCI-S-009-2012 and small RC slab specimen were conducted to identify the restrained expansion properties. In terms of structural level, the covercrete quality and cracking conditions were investigated.

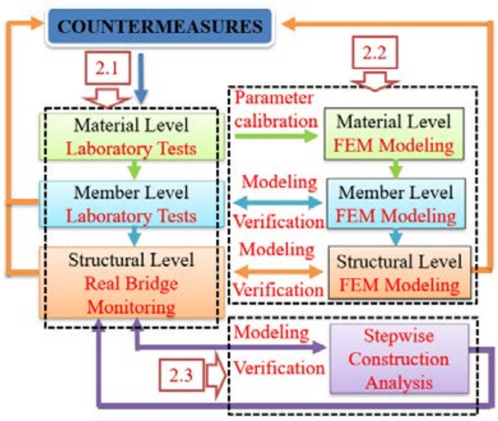

Fig. 1 Research methodology

2.2 FEM modeling and verifications

FEM modeling was performed based on material and member level laboratory tests. The calibrated parameters in material and member level including material properties input, adiabatic temperature rise model, strength development model, autogenous shrinkage model, expansion strain properties input, reduction factor considering creep effect and thermal properties of related heat insulation materials were applied to the full-scale structural level of Fudaigawa bridge. Full-scale thermal stress simulation was conducted to analyze influential factors for cracking.

2.3 Stepwise construction analysis

The stepwise concrete placement of the RC deck slab of Fudaigawa bridge was simulated based on the nonlinear stress analysis incorporating nonlinear material model, and layered fiber model for steel girder and RC slab. In the simulation model, the appropriate concrete volume and the placing sequence were investigated in order to mitigate generated stresses during construction works.

3. RESULTS AND DISCUSSIONS

3.1. Stress due to stepwise construction

The deck slab of Fudaigawa bridge was divided into nine lots (mainly seven lots except two small end lots) for concrete placement, where the maximum length of each lot was decided based on the maximum working capacity of concrete volume (around 150m^3). The analysis results showed that the interior support lots (lot 3, 5, 7) should be placed after finishing exterior support and middle span lots (lot 1, 2, 4, 6, 8, 9). Among exterior support and middle-span lots, the longer lots should be placed earlier. In addition, the larger the concrete volume of interior support lots (Lot 3, 5, 7), the smaller the tensile stress due to stepwise construction will be generated. Consequently, the final stepwise construction method was decided, as shown in Fig. 2. The maximum generated tensile stresses due to stepwise construction were calculated in lot 4 and lot 8 as 0.79N/mm^2 and 0.72N/mm^2, respectively. These stresses, lower than 0.8N/mm^2, were

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smaller than stresses of about 1.4 N/mm^2 calculated in the equivalent four-span Kosano bridge. For further cracking mitigation, increased expansive additive with 25kg/m^3 was applied to those two lots to minimize the total tensile stress generated in the RC deck slab.

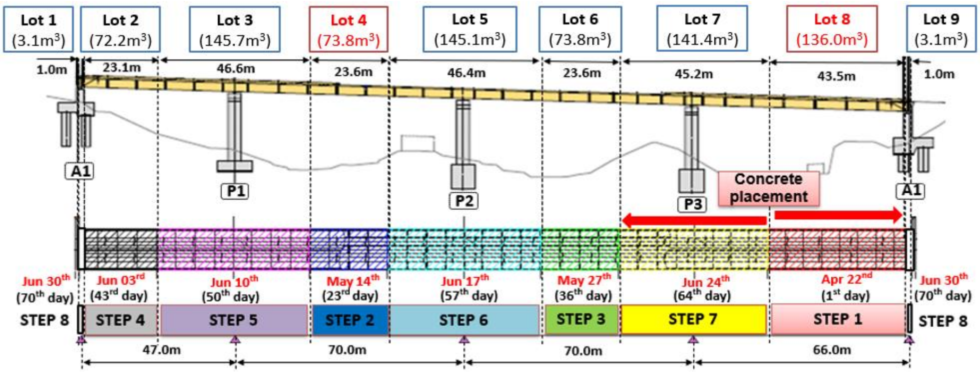

Fig. 2 Stepwise construction method of Fudaigawa bridge

3.2. Thermal stress development considering the increased expansive additive with 25kg/m^3

The utilization of expansive additive for compensating shrinkage of concrete resulting in tensile stress reduction was introduced in many studies. However, it was confirmed that many transverse cracks appeared on the slabs upon continuous steel girder with more than three spans after 28 days of wet curing period when 20kg/m^3 of expansive additive was added. Therefore, increasing the amount of expansive additive to 25kg/m^3 was proposed in Fudaigawa bridge (at lot 4 and lot 8).

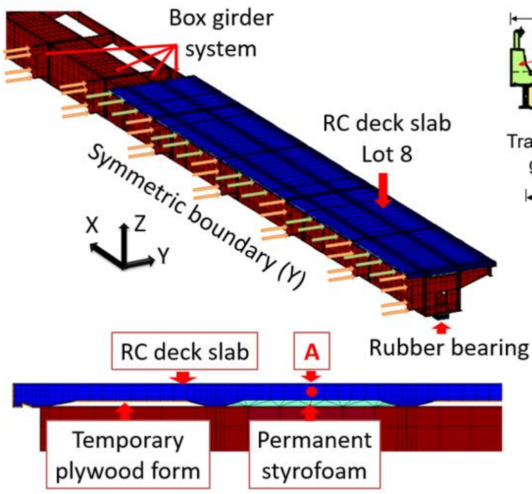

Fig. 3 Full-scale symmetric Fudaigawa bridge FEM model

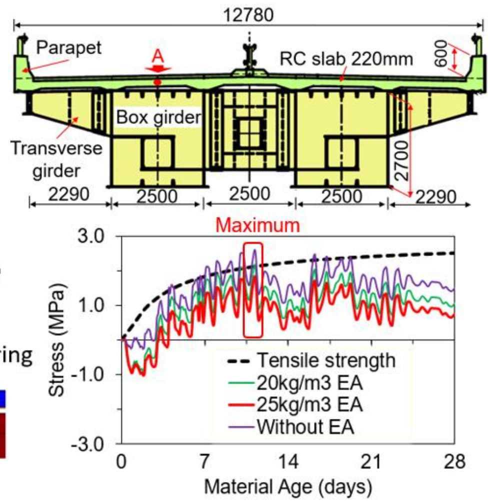

Fig. 4 Simulation of longitudinal stress in RC deck slab at location A

The three leveled systematic FEM modeling (in sections 2.1 and 2.2) was applied for analyzing the thermal stress in lot 8. The full-scale symmetric Fudaigawa bridge FEM model consists of an RC deck slab (lot 8), steel box girder system, temporary plywood form, permanent styrofoam and rubber bearing, as shown in Fig. 3. According to Fig. 4, the longitudinal stress at location A in lot 8 varied depending on the expansive additive dosage. The use of 25kg/m^3 expansive additive showed the lowest maximum tensile stress, 1.79MPa, compared to the case with 20kg/m^3 and without using expansive additive, 2.13MPa and 2.56MPa, respectively.

3.3. The new joint system to prevent penetration of vertical cracking in parapet walls into RC deck slab

In parapet walls of Fudaigawa bridge, all the joints were made into V-cut joints to control cracking, as shown in Fig. 5.

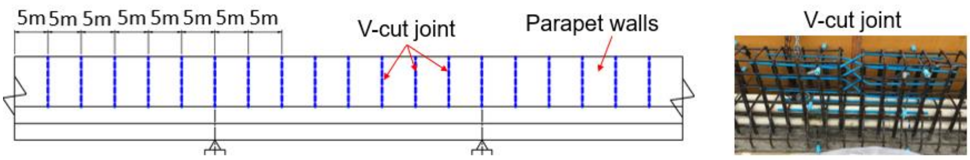

Fig. 5 New joint system in parapet walls

3.4. Cracking investigations

According to the structural cracking investigations conducted at about two months after placing the last RC lot, it was confirmed that there was no transverse crack generated on the top surface though some microcracking was found in a very limited area (in lot 8) and only one very minor transverse cracking at the bottom surface in lot 4. Additionally, the vertical cracking generated in parapet walls was mostly controlled without propagating into the deck slab, PHAN et al. (2021).

4. CONCLUSIONS

The applied countermeasures to Fudaigawa bridge considering sophisticated stepwise construction method, increased expansive additive with 25kg/m^3 and the new joint system to control vertical cracking in parapet walls showed their efficiency to mitigate the risk of cracking in the RC deck slab.

REFERENCES

PHAN, N. T., HOSODA, A., TSUJITA, Y., and SHIRAKAWA, A.: Mitigation of Cracking in Durable RC Deck Slab on Multiple Span Steel Box Girder Considering Stepwise Construction Method and Utilizing Expansive Additive, JCI Annual Proceedings of Concrete Engineering, Japan, 2021 (accepted)