LESSONS LEARNED OF ULTRA-RAPID HARDENING CONCRETE APPLICATION FOR BRIDGE DECK SLAB REPAIR AND STRENGTHENING IN LAOS

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1. INTRODUCTION

As a result of the bridge inspection of the Na-Mone bridge in Vientiane province, Laos, on national-road number 13 North (NR13N), damage such as cracks and falling part of concrete on the bridge deck was found. Since inadequate thickness of the existing bridge deck was considered as the main reason of damage, the method of increasing thickness and partial replacement of the bridge deck was evaluated for repair/ reinforcement. However, since no detour route is available, "Ultra-Rapid Hardening Concrete"(URHC) which had not been applied in Laos was firstly applied to minimize the social impact for the case of road closing for the repair/ reinforcement works. By applying URHC, the period to traffic opening after casting concrete was expected to reduce from 28 days to three hours. This report covers the result and processes of URHC application, including trial mix and construction, and lessons learned from them.

2. BRIDGE DETAIL AND CONDITION

The Na-Mone Bridge, constructed in 1991, is located on NR13N. The bridge has two spans with four precast post-tensioned girders 22 meters long, and the total span is 46.08 m, 7.3 m in width. The deck slab was thin, about 16 cm.

3. PRODUCT INFORMATION

Ultra-Rapid Hardening Concrete, “Sho-Bond Compact Jet CPJ (CPJ),” produced by SHO-BOND Corporation, was applied for the repair/ reinforcement work. CPJ is a special cement admixture that can be mixed with a simple type of port-land cement (PL) and it achieves the compressive strength of 24 N/mm2 in 3 hours. It is possible to mix with a general concrete mixer, but quick to harden, so it requires special attention for the mixing control.

4. INITIAL STUDY, TRAIL MIX (LABORATORY AND PLANT MIX)

As the mixing method, CPJ was added with retarder(R) into normal concrete with certain design strength. The mix proportion is 70 and 30 percent for PL and CPJ accordingly, the final water per powder (P=PL+CPJ) is between 35-38 percent. The compatibility tests were conducted in Japan using cement made in Laos. After that, a trial mix was conducted at the Public Works and Transport Institute in Laos. The trials were examined for four different proportions, and their workability were tested before adding the CPJ. Table 1 shows the mixed proportion of the four trials. The plant trials, the concrete was ordered from the mixing plant, and a class 30 of concrete was picked for the trial to simulate the mixing method for actual construction. The 150 liters of fresh concrete with the designed amount of CPJ and its retarder were applied. The slump and temperature of the fresh mix were examined before and after CPJ mixing. The application rate of each material was confirmed from this stage.

Table 1 Trail Laboratory mix portion detail

Mix No.	*Water/W(kg)*	*Cement/C (kg)*	*Gravel (kg)*	*Sand (kg)*	*CPJ (kg)*	*R(g)*	*W/C*	*W/P*	*Slump (cm)*	*Average 3 hours compressive strength*
1	7.4	16	42	27.2	6.86	137	0.46	0.32	18	29.3 Mpa
2	7.2	14	42	27.2	6	120	0.5	0.36	23	25.7 Mpa
3	5.6	12	42	27.2	5.14	103	0.47	0.33	15	20.8 Mpa
4	6.2	14	42	27.2	6	120	0.44	0.31	16	24.3 Mpa

5. SITE CONSTRUCTION, QUALITY CONTROL AND MONITORING

(1) Partial replacement of the bridge deck

For the partial replacement of the bridge deck, the repair area of concrete was removed, and arranged reinforcement bars.

Figure 1 Procedure of partial replacement

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Table 2 Concrete casting record and compressive testing result

Date	*Time of Casting*	*Casting Amount*	*Purpose*	*Fresh concrete properties before CPJ adding*	*Age (Hours)*	*Average Compression Strength (Mpa)*
20 Feb 2023	Morning	≒1.05m3	Sectional Deck Repair	Slump: 4.5cm, Concrete Temperature: 26.5℃	3.5 27	32.0 41.7
20 Feb 2023	Night	≒3.3m3	Deck thickness increasing	Slump: 16.0 cm, Concrete Temperature: 31.7℃	15.5	29.0
21 Feb 2023	Night	≒0.75m3		Slump: 0.0 cm, Concrete Temperature: 32.3℃	19	42.0
22 Feb 2023	Morning	≒3.0m3		Slump: 14.5cm, Concrete Temperature: 25.9℃	6	37.7
23 Feb 2023	Noon	≒3.6m3		Slump: 21.0cm, Concrete Temperature: 31.7℃	3	29.4

For increasing the bonding strength between the existing bridge deck and the newly casting deck, primer was applied as the bonding agent before casting URHC using the same material as the 2nd batch of plant trials.
The construction process is described in Figure 1. Fresh mixes were checked for their properties, cylindrical concrete samples were collected and tested for several ages to ensure to meet the target strength of more than 24 N/mm2.

Figure 2 Procedure of the method of increasing thickness

(2) Increasing thickness of the bridge deck and issues occurred
The construction process for increasing the thickness of the bridge deck is described in Figure 2. Increasing the thickness of the bridge deck was also completed successively, and it upgraded from a thickness of 16cm to 21cm at least as described in the repair design document of the project. However, several cracks were found after the traffic reopened: the cracks occurred partially on the newly-paved bridge surface after one week and gradually developed and emerged in the full area after two weeks. As possible reasons of these cracks, dry shrinkage, partial inadequate bonding, and overloading are considered. However, these have not been determined yet as of now, although the technical investigation has been done particularly.

6. RESULT AND LESSONS OF CPJ APPLICATION FOR BRIDGE SLAB OVERLAY

As a result of the first application of URHC in Laos on the pilot repair project, the strength of the concrete successfully fulfilled the required value (24 N/mm2), besides the social impact for the case of road closing was also minimized, as expected.
On the other hand, through this case, matters and lessons learned were found as follows: The training for labor was insufficient since the trial application of the material was not fully done before actual construction. A represented site should be prepared and done for concrete casting, to observe the construction techniques, and train the labor on how to deal with the super-accelerated hardening time of concrete, and how to cure it properly and successively reduce human errors.
The raw material should be done for mechanical properties testing, such as water content and water absorption of the material to erase an error in mixing water. As indicated in Table 2, material qualities were unstable since the slump value before CPJ adding are huge variants from 0 to 21 cm and the concrete temperature also had a big deviation. The thickness of the new laying layer is thinner and bonding between the existing substrate and the new concrete layer must be firmed. Therefore, special care must be executed, the construction manual and particular quality control techniques of concrete construction are the most important and should be established and well-trained before a UHRC construction.

7. CONCLUSION

For the repair/ reinforcement of the Na-Mone bridge in Vientiane province, Laos, on NR13N, the increasing thickness and partial replacement of the deck slab were selected, and UHRC was applied as the first case in Laos. Casting UHRC was completed according to prior planning. However, cracks occurred after the construction, then several technical lessons were reviewed, and further study will be done to confirm the cause of damage and improve the construction method.

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