**Link Slab Study**

Phase I study involves the execution of the following tasks:

**Task 1 – Conduct literature review from the federal and other state agencies**

The focus of this phase is to locate, collect and list all the available current state-of-the-practice methods for (1) FHWA's regulations, (2) Other states' practices, and (3) Research and testing findings. Contacts made to members of the AASHTO Subcommittees on Bridges and Structures, T-04 Construction and T-10 Concrete Design. Also contacts are made to contractors and design engineers.

**Task 2 – Perform laboratory testing**

Table 1 – Materials for link slab

| Candidate | Note |
|---|---|
| RC Slab | Common reinforced concrete link slabs (Since 1989) |
| LMC with Rapid Set Cement | High early strength |
| FRP | Fiberglass-reinforced plastic (Not many applications) |
| Ductile ECC | Better structural performance<br>(Lower reinforcement ratio but better cracks control) |
| FRC with Polypropylene or Steel Fibers | VDOT/ VTRC Tested |
| UHPC | Applied in NY states since 2008 |

Two of the six types of materials listed above are tested. Laboratory tests are performed to determine the flexural strength for the link slab. It is estimated two types of material for two (up to three) samples each for a total of four (up to six) test specimens.

(a) Small Mixer

(b) Large Mixer

(c) PVA fiber


(d) Mixing Material - Fiber, Cement. Sand, Fly ash, Water reducer (not shown), and Water

Figure 1 – ECC lab mixes at Ready Mix Concrete Lab in Greenbelt, MD

**Task 3 – Select and analyze a bridge for pilot study**

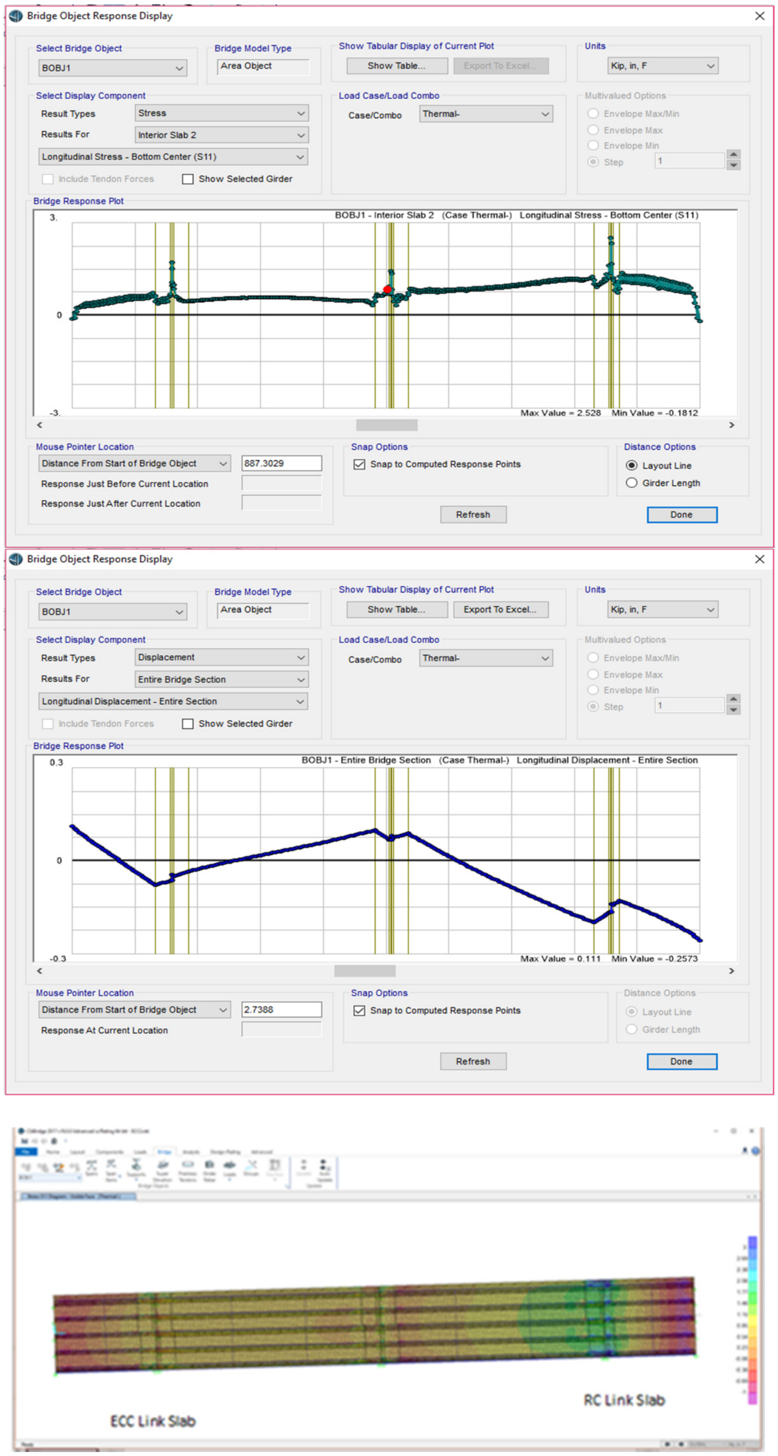
The research team works with MDTA and a designated consultant firm on selecting a sample bridge. Plans of the existing bridge are collected. Pilot study is conduct on this selected bridge with the best performed material from the laboratory tests for link slab application. Numerical study, including Finite Element Analysis (FEA), is performed for the deck movement due to temperature, shrinkage, and creep effects. Requirement of the flexural strength as well as horizontal and rotation movement are investigated to correlate the field performance.

**Task 4 - Provide recommendation of standard practice**

As mentioned, two (or three, if required) types of practices are studied. Cost and practicality are consulted and collaborated with designers and contractors. As such, an economical and practical design is recommended.

**Task 5 - Summary and Report**

A summary of all four tasks listed above is included in the final report. Recommendations associated with an economical and practical design, complemented with the study of tests, are included in the report. A presentation session is planned and included in this task.




(a) Thermal movement for temperature increase

(b) Stresses at top of the slab for temperature increase

(c) Stress contour at top of the slab for temperature increase

Figure 11 – Thermal movement at bearings and stress/stress contour at the top of the slab for bridges with ECC link slab

Phase II study involves the execution of the following tasks:

**Task 1 –Boundary Condition Investigation**

Link slab studies by Gastal and Zia (1989) included a finite element (FE) analysis that was validated by several simply supported beam tests. Investigation of the influence of roller (R) and hinge (H) support conditions on link slab stresses revealed that the link was in tension and provided some degree of live load continuity under double-hinged condition at the center support (RHHR). For the double-roller condition at the center support (HRRH), analyses showed that the deck link was under compression and the beams acted as simply supported. Richardson (1989) and El-Safty (1994) indicated the influence of support conditions on deck stresses and potential deck cracking. However, Zia et al. (195) and Caner and Zia (1998) concluded that link slab behavior is independent of beam-end support conditions underneath the link slab and the conclusions were validated by test data and numerical simulations. Okeil and El-Safty (1994) later contradicted this finding, indicating that under live load, the link slab would be in tension regardless of the support conditions. Okeil and El-Safty (1994) stated that the tension force developed in the link slab for HRRH case would be smaller than that of RHHR case because of unrestrained horizontal movements at the interior supports. The discrepancies with earlier conclusions by Zia et al. (1995) were rationalized by stating that the slightest inward movement of the supports would relieve the tensile force in the link slab. Test results presented by Zia et al. (1995) did not provide data on support movements.

In the FHWA UHPC study on link slab connections, bearings under steel girders at the connections are designed to allow both rotation and longitudinal movements, thus minimizing the negative moments transferred between spans and the forces imparted to the connection. It is expected that if any cracking were to occur in this detail, it would be tightly spaced and would limit any water ingress to the structure elements below.

In Michigan's study on using ECC for the link slab, β factor was introduced in the link slab design process for cases of joints with two roller bearings (one for each adjacent span) and joints with one roller bearing and one pin bearing for adjacent spans or joints with two pin bearings. For joints with two roller bearings located at the link slab, the link slab must be able to accommodate the thermal deformation from both adjacent spans simultaneously. For joints with one or two pin bearings, the ECC link slab only has to accommodate thermal deformation from one adjacent span.

The study of different boundary conditions is evaluated in this Phase II study. The purpose is to find the feasible span ranges without changing the boundary conditions. Preliminary study has been made in Phase I and is more extensively studied in Phase II. Conclusion is made on various boundary conditions for their limitation on the application.

**Task 2 - Link slab design procedure**

Full slab depth (usually 8" deep) with full two-layer reinforcement for ECC and 4" thickness with light one-layer reinforcement for UHPC are studied. Final design is prepared with all limit states considered

**Task 3 - Link slab special provision**

Steel gird deck with link slab implementation is studied. As mentioned, due to the high cost of UHPC, special cases, such as grid slab, can be considered for application. Structural details are collected and details are developed in this study.

**Task 4 - Link slab typical details and specifications**

Details based on the design procedure and special provisions for both ECC and UHPC and the specifications for field applications are provided..

**Task 5 - Summary and Report**

A summary of all four tasks listed above is included in the final report. Recommendations associated with an economical and practical design, complemented with the study of tests, are included in the report. A presentation session is planned and included in this task.

**Task 6 – Optional Pilot Implementation**

Load test and relatively long-term monitoring are performed. Thermal movement plus the strain (stress) measurement are monitored. This final version of the proposal is based on with monitoring.