Research Summary

South Carolina Department of Transportation | Office of Materials and Research

Project Information

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SAFE AND COST-EFFECTIVE REDUCTION OF LOAD POSTINGS FOR SOUTH CAROLINA BRIDGES

South Carolina (SC) has over 9,000 bridges in its inventory, many of which were designed for H10 or H15 truck loads. Precast reinforced concrete flat slabs are the primary bridge type investigated due to their prevalence in the bridge inventory; flat slab bridges account for approximately 1/3 of all bridges in SC. The challenges associated with these components include a) original structural design loads that are lower than those used today and b) ages approaching or exceeding expected lifespan in combination with deterioration. The focus of the project is to safely remove load postings associated with this bridge type in South Carolina.

Precast reinforced concrete flat slab bridge

Problem

Precast reinforced concrete flat slabs bridges are very common in the bridge inventory of SC and resolving associated performance issues will therefore have wide-ranging impact. Challenges include a) original structural design loads that are lower than those used today. and b) ages approaching or exceeding expected lifespan in combination with deterioration.

A particular challenge with this bridge type is that load ratings are frequently not met as these bridges were originally designed for lower levels of truck loading than those required today. Flexure is the primary mode that presents a challenge for this bridge type.

Research

The research had a two-pronged approach. First, the project investigated the flexural capacity of precast slab components without any modifications. These investigations provided an estimate of the in-situ strength of slab bridges currently in service. With information on the in-situ strength, the SCDOT can make informed decisions regarding removal or maintaining of load postings. Second, the project investigated schemes for strengthening slabs. These schemes can be deployed when analysis

and circumstance require the need for increased capacity above and beyond the existing in-situ strength.

Twelve unstrengthened precast concrete slab specimens were load tested to determine their flexural capacity. Some of the slabs were salvaged from a recently decommissioned bridge, others were taken from storage yards at SCDOT facilities. On average, the experimental moment capacity of the slabs was 65% greater than the calculated capacity. This result is attributed to a) stronger than specified concrete strength, b) stronger than specified reinforcement strength, c) horizontal restraint at the bearings (i.e. supports did not behavior as pin-roller), and d) greater than specified flexure depth of the reinforcement. Each of these possible reasons for the increased strength was supported by material testing, parametric tests, and/or physical observations.

Strengthening strategies to increase moment capacity of flat slabs were investigated. After a state-of-practice review, four strategies were implemented in the laboratory as proof-of-concept tests. The four strategies selected for further study were: a) attachment of steel sections to the top of the bridge deck: accomplished by either attaching two C10 x 15.3 channels to the top, or by attaching two 0.5 in. x 16 in. steel plates to the top, b) attachment of steel plates to the bottom of the bridge deck: strengthening from below was achieved by attaching plates on the bottom of the slab using four variations of plate size and attachment schemes, c) external post-tensioning attached to the deck bottom: strengthening by external post-tensioning was achieved by suspending and prestressing three 5/8 in. diameter DYWIDAG thread bars between two steel angle sections attached to the bottom of the slab, and d) near-surface mounted bars: #6 bars were embedded into the surface of two slabs in series to create one continuous slab with two spans. This is called a strengthening technique but in reality it reduces the design load on the bridge by creating two continuous spans.

Strengthened slab test setup with two steel channels on top

Results

Experiments show that steel plates on the surface gave the lowest strength increase, while post-tensioning with mechanically torqued tension rods on the bottom gave the highest strength increase. Cost-benefit analysis reveals that strengthening from above is more costly in terms of materials, but due to constructability and access difficulties, strengthening from below is more expensive overall.

The findings are provided below:

1. In general, strengthening from below will increase capacity more than strengthening from above (excluding near surface mounted from above).
2. The two least costly methods were strengthening from above with near surface mounted steel bars and steel channels.
3. The least costly method is associated with the target increase with respect to measured capacity. In the range of 15% increase, strengthening with steel channels from above is the most efficient method. For 15-25%, using near surface mounted steel bars from above to reduce design loads is preferred. Beyond 25% increase, steel plates from below were found to be the most efficient method.
4. The in-situ strength of precast slab bridges is likely stronger than theoretical capacity due to stronger than specified materials, restraints provided by bearings, and/or greater than specified effective depth of steel reinforcement.

Recommendations for future work:

1. Deploy selected strengthening methods in the field and monitor performance over time.
2. Further investigate drone inspection, data analysis, and asset management software to further reduce costs and enhance safety.

Value & Benefit

The findings of this research offer a solution to reduce the number of bridge load postings in SC through improved understanding of behavior and cost-effectively increasing strength. The study specifically focused on identifying the most efficient and cost-effective approaches to strengthening. The results and findings suggest that the most efficient means of strengthening depend upon the desired target increase in moment capacity.

Means of strengthening from above are very cost effective, whereas strengthening from below may be needed when higher increases in strength are needed. The implementation of the approaches outlined has the potential to improve the structural integrity of bridges and extend their useful life, thereby reducing the need for bridge load postings.

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