Service Performance of Bridge Approach Slabs

RESULTS: Service performance of approach slabs degraded by void formation underneath the slab is examined by load testing. Four full-size approach slab specimens were tested under increasing magnitude up to 4 times AASHTO HS20-44 design truck loads. Test slabs included the following details: (i) conventional steel reinforcement representative of current California design, (ii) steel reinforcement replaced by a double-layer pultruded fiber-reinforced polymer grating, (iii) steel reinforcement replaced by glass fiber-reinforced polymer rebars, and (iv) incorporation of steel and polyvinyl alcohol fibers in the concrete mix and removal of top longitudinal and transverse steel. Tests revealed that these slabs exhibit similar performance in terms of stiffness, deformation, and crack pattern when fully supported, but registered noticeable difference in performance under deteriorating soil washout conditions. The fiber-reinforced concrete slab showed the best crack control, the smallest deflection and end rotation among the four test slabs.

Motivation
Consolidation of underlying natural foundation soil, compressive deformation of fill materials and erosion of approach embankment often result in significant differential settlement between the bridge structure and the approach pavement. The differential settlement, commonly referred to as "the-bump-at-the end-of-the-bridge", was estimated to affect about 150,000 bridges in the US [1]. The settlement leads to uneven road surface and deteriorates the ride comfort of the traveling public. The uneven surface is commonly mitigated by an approach slab to enable a smooth transition between the roadway and the bridge deck, which in turn reduces the dynamic load imposed by heavy trucks on the bridge.

Current construction of approach slabs relies on cast-in-place reinforced concrete slab with dowel anchorage into the abutment or threaded rod and nut system into the bridge deck. Despite their extensive use, there is no uniform design of approach slabs across the US, which may have contributed to the poor performance of approach slabs in many states. Factors contributing to their unsatisfactory performance include (i) time-dependent consolidation of the natural soil under the embankment and fill material due to inadequate compaction, (ii) poor drainage behind the bridge abutment resulting in erosion of the fill material and void formation under the approach slab, and (iii) longitudinal and vertical translations as well as rotation of the abutment causing localized damage at the connection of the approach slab. Distress in the approach slab often manifests itself in the form of transverse and/or longitudinal cracks, which invariably reduces the service life of the slab and increases the maintenance/repair costs of the structure.

Implementation
Cracking in bridge approach slabs is often unavoidable under service load conditions. Under repeated traffic loading, small initial cracks grow in size and length, and gradually degrade the integrity of the slab. In some cases, worsening cracks permit aggressive chemicals such as chlorides to enter the concrete, causing eventual corrosion of the steel reinforcement.

A testing program was conducted with an objective aimed at reducing the maintenance cost by using durable and cost-effective replacement alternatives. Test slabs with details representative of current Caltrans design were tested under simulated truck load up to 4 times AASHTO HS20-44 design truck. All slab specimens were 30' long, 12' wide and 12" thick (Figure 1). The length of the specimen corresponded to the current length of approach slabs in California, and the width corresponded to the width of one traffic lane in the US. In addition to the truck load being a test parameter, deteriorating support condition as a result of washout of fill materials was incorporated into the loading protocol. Service performance of the approach slab, in particular with reference to ride comfort, was examined for an 'as-built' approach slab specimen as well as three replacement alternatives. Maximum tolerable washout length before initiation of remediation was established on the basis of these performance criteria.

Test matrix included (i) a conventional steel reinforcement slab with details of the current Caltrans...
R(9S) slab, (ii) a non-metallically reinforced slab with 100% of the steel reinforcement replaced by a double-layer pultruded fiber-reinforced polymer grating (Gridform), (iii) a non-metallically reinforced slab with 100% of the steel reinforcement replaced by E-glass fiber-reinforced polymer rebar, and (iv) a steel reinforced concrete slab with steel fibers (0.5% by volume) and polyvinyl alcohol fiber (0.2% by volume) added to the concrete and with the top longitudinal and transverse steel removed from the reinforcement.

Research Results

Figures 2(a)-(d) show the vertical load-deflection response of the test slabs from a fully supported condition to washout lengths of 4', 8', 12' and 16'. Actual load cycles were carried out in 2' washout increment, but for the purpose of clarity, only washout in 4' increment were plotted in these figures. The y-axis in the figure corresponds to the total force applied to the slab i.e. sum of four wheel loads, whereas the x-axis corresponds to the slab deflection measured at the centroid of the four wheel loads. Loading on the slab consisted of 3 cycles to 100% HS20-44, followed by 3 cycles to 200%, 3 cycles to 300%, and 3 cycles to 400% of HS20-44. All four slabs were able to resist the maximum compressive load of 256 kips, or 4 times HS20-44, without experiencing flexural or shear failures. The load-deflection curves were almost linear up to 256 kips for a washout length up to 8' for all four specimens.

Tests indicated that the gravity load applied on fully supported approach slab was transmitted by direct bearing of the slab on the soil without any significant bending. Consequently, the deformation of the slab was characterized by a very large vertical stiffness. Under washout conditions, however, the slab was seen to exhibit stiffness reduction, particularly after a certain washout length. Test results indicated that the stiffness reduction became significant after 6' washout, suggesting that a good washout length limit for considering remedial measures is approximately 6'. The reserve stiffness of the test slabs was about 90% of the slab's original stiffness at that washout length.

All test slabs showed similar performance in terms of deformation and crack pattern when the slab was fully supported by well compacted soil. Under deteriorating washout conditions, however, these slabs exhibited noticeable difference in crack width and distribution. The use of steel and polyvinyl alcohol fibers, at dosage of 0.5% and 0.2% by volume, respectively, showed the best crack control among the four slabs. Despite the absence of top reinforcement, the fiber-reinforced concrete slab showed fewer top surface cracks compared to the conventional approach slab, which included top steel reinforcement. Top and bottom cracks were also noted in the fiber-reinforced concrete slab later than other three slabs and at longer washout lengths. The fiber-reinforced concrete slab also showed the smallest deflection as well as end rotation among the four slabs. Compared to the conventional steel reinforcement slab, fiber-reinforced concrete slab showed a smaller deflection and end rotation but the difference was not significant.

Reference