ABSTRACT

Cast in-situ Short Paneled Concrete Pavement (CiSPCP) or Short Jointed Plain Cement Concrete Pavement (SJPCP) is relatively new type of pavement with slab size in the order of 0.5 m x 0.5 m to 2.0 m x 2.0 m with reduced thickness compared to conventional Jointed Plain Concrete Pavements (JPCP) of size 3.5 m x 4.5 m for same design traffic. These types of pavements are constructed with normal Paving Grade Quality Concrete (PQC), similar to JPCP, with or without fibers placed on Lean Concrete (LC) base, Cement-Treated Subbase (CTSB), and subgrade, thus forming a strong foundation. The short slabs or panels are formed by introducing the saw-cuts of 3 to 5 mm width and depth of $1/4^{th}$ to $1/3^{rd}$ thickness of the slab within 8 to 16 hours of concrete placement. The purpose of saw-cut is to reduce drying shrinkage stresses and to produce controlled full-depth cracks during the service life. Load transfer in CiSPCP is achieved by aggregate interlocking. It generally does not require load transfer devices such as dowel bars, unlike JPCP, making it an economical solution. As length of the slab decreases, the thermal stresses decrease significantly. However, load stresses increase with a reduction in the thickness and length of the slab. The strong foundation provided below the concrete slab of CiSPCP should be able to resist the higher magnitude of load-induced stresses. The load transfer mechanism across contraction joints of CiSPCP needs to be studied as limited works were reported on this. Numerous works were reported on failure criteria, the curling behavior, field studies, stress computation, and the design of JPCP. However, limited works have been carried out on CiSPCP on these aspects.

Keeping the above in view, the broad objective of the present study is proposed as development of design methodology for CiSPCP for high-volume roads based on experimental and numerical investigations. For this purpose, CiSPCP test sections on LC were proposed, a preliminary analysis was carried out. A Three-Dimensional Finite Element (3D FE) single slab analysis model was developed and used for calculating slab geometry of test section for selected design input parameters. Construction of CiSPCP test section of (i) 384 m length on NH-19 (test section-I) with 1.0 m x 1.0 m size and 180 mm thickness and (ii) 1500 m length on NH-18 (test section – II) with varying (a) slab thickness (180, 200, and 220 mm), (b) size of the slab (1.0 m x 1.0 m, 1.5 m x 1.5 m and 2.0 m x 2.0 m) and (c) with and without separation membrane (non-woven geotextile) on LC base, CTSB and subgrade were done.

The effect of (i) aggregate size (10 mm and 20 mm Nominal Maximum Aggregate Size -NMAS) at three stress levels (80, 85, and 90% of flexural strength of concrete) and three frequencies (2, 5, and 10 Hz), and (b) microfiber (0.0, 0.9, 2.0, and 3.0 kg/m^3 dosages) at three stress levels (80, 85, and 90%) and one frequency level (5 Hz) on the flexural fatigue characteristics of concrete was evaluated. Based on laboratory evaluation, concrete mix (PQC) with microfiber was chosen to construct two CiSPCP test sections.

Further periodical performance evaluation of test sections by falling weight deflectometer (FWD) was carried out to measure surface deflections at different locations of concrete slab for four years. These surface deflections were analyzed for Load Transfer Efficiency (LTE) of joints and backcalculation of pavement layer properties. The crack-width measurement, curling behavior of slabs, and road roughness (riding quality) measurements using a Network Survey Vehicle (NSV) were also carried out to understand the behavior of CiSPCP. From surface deflection data, relationships between LTE, Differential Deflection (DD), and crack width (joint opening) were developed. For the analysis of CiSPCP, 3D FE multi-slab analysis model was developed. The model was calibrated using field test section data, i.e., surface deflection parameters at corner and edge region of the slab and LTE of joints.

The calibrated 3D FE model was used to analyze the CiSPCP for different load positions based on expected failures and combination of both wheel load and temperature gradient. Further design methodology of CiSPCP for high-volume roads based on Cumulative Fatigue Damage (CFD) was proposed, and calibrated model was used to develop design charts from tensile stress of different thicknesses of slab size. The regression equations were also developed for various slab sizes from the obtained stress magnitudes.

An illustrative design example was presented and verified the adequacy of design of CiSPCP test sections. Conclusions were drawn and reported based on extensive field investigations, analysis, and design of CiSPCP. The suggested design methodology for CiSPCP placed on a strong foundation (LC and CTSB) would substantially reduce the slab thickness compared to conventional JPCP. Therefore, it is expected that adoption of CiSPCP would be beneficial for highway community and helps to achieve sustainability in road construction.

Keywords:

3D FE multi slab analysis; Cast-in-situ short paneled concrete pavements (CiSPCP); Curling behavior; Design methodology for CiSPCP; Falling Weight Deflectometer (FWD); Load transfer efficiency (LTE) of joints; Test sections