International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Mathematical Modelling of Engineering Problems
Vol. 10, No. 5, October, 2023, pp. 1893-1900
Journal homepage: http://iieta.org/journals/mmep

A Parametric Study of Bridge Approach Slabs under Vehicle Loads Using SAP2000

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https://doi.org/10.18280/mmep.100543

Received: 26 June 2023
Revised: 5 August 2023
Accepted: 15 August 2023
Available online: 27 October 2023

Keywords:
approach slab, bridge, soil-structure interaction, SAP2000, settlement

ABSTRACT

The transitional zone between a bridge and its adjoining roadway, known as the bridge approach, frequently experiences differential settlement. This study employs the three-dimensional finite element software SAP2000 V22 to rigorously examine the performance of bridge approach slabs under vehicular loads, with a particular focus on the interaction between the slabs and embankment settlement. Bridge approach slabs and soil are modelled using shell and solid elements, respectively, with the soil characterized by the Drucker-Prager material model. A comprehensive investigation is undertaken to evaluate the effects of various soil and slab parameters on the system's performance, including slab thickness, slab length, approach slab restriction, fill material thickness, and soil's elastic modulus. Furthermore, a sensitivity analysis considering different boundary conditions is also conducted. The outcomes of the analysis include predicted slab deformations and bending moments under design traffic loads. Notably, a correlation is found between increased settlement and approach slab length at the slab's unrestricted boundary, particularly for soils of lower stiffness. The results also suggest that enhancing the compacted fill material thickness and the soil's elastic modulus can reduce slab deflection. The boundary condition and thickness of the slab are identified as key determinants of settlement values. These findings offer valuable insights for engineering professionals aiming to optimize bridge approach slab design, thereby boosting structural integrity and durability.

1. INTRODUCTION

The bridge approach, a critical facet of road-bridge structures, enables an effortless transition between the roadway pavement and the bridge structure itself. However, settlement at bridge approaches presents a significant challenge to these systems, potentially leading to the formation of bumps at bridge ends, which can cause accidents and demand high maintenance costs [1].

Various factors can trigger excessive settlement of the approach slab, including inadequate drainage, settlement of the backfill, and consolidation of the naturally occurring soils [2-5]. To address this issue, several techniques have been proposed by researchers, with a majority grounded in the principles of soil improvement. Among these, the implementation of a concrete slab is recognized as one of the most effective strategies for mitigating settlement in this zone.

Numerous studies have been conducted to inspect the efficacy of approach slabs in this regard. Owing to the complexity inherent in this zone, these studies predominantly employ two or three-dimensional finite element analysis. For instance, Cai et al. [6] utilized three-dimensional finite element analysis via ANSYS software, considering the interaction between the soil and the bridge approach slab during embankment soil settlement. Their findings illustrated the utility of finite element procedures in designing approach slabs for specified embankment settlements. Furthermore, they undertook parametric studies to develop a straightforward design procedure, with the intention of bypassing the need for complex finite element analysis in routine designs.

Similarly, Khodair and Nassif [7] leveraged the finite element software ABAQUS 2D to simulate the cracking behavior of bridge approach and transition slabs, accounting for various types of materials and boundaries. Their results suggested that a substantial increase in the approach slab's cracking load-carrying capacity can be achieved by increasing the slab thickness. Conversely, they also noted that elevated soil settlement adversely affects its cracking load-bearing capacity.

Geotechnical and structural elements significantly impact the performance of the approach slab. In this context, Thiagarajan et al. [8] employed a 3D finite element computer program, SAP 2000, to simulate the approach slab, examining its behavior under varying embankment settlements. The study took into account the interaction between the bridge approach and the soil, utilizing the beam-on-elastic-foundation concept. The objective was to devise a cost-effective approach slab. A comprehensive parametric study was carried out to ascertain the effects of slab thickness, slab length variations, slab end restrictions, and sand loss at support conditions. The study presented two solutions: new construction designs using cast-in-place, pre-cast pre-stressed slab designs for new constructions, and substitute approach slabs.

Similarly, Rajek [9] investigated the performance of the approach slab under different conditions, using a parametric analysis with 2D finite element analysis via the ABAQUS program. The study used the Mohr-Coulomb simulation to represent soil layers, concluding that soil and concrete