Analysis of Pavement Distress Using Benkelman Beam Deflection Method

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ABSTRACT

This manuscript presents a comprehensive analysis of pavement distress assessment using the Benkelman Beam deflection method in flexible pavements. The study aims to evaluate the structural capacity and performance of pavement sections under repeated wheel loads by measuring surface deflections and correlating them with distress indicators such as cracking, rutting, and permanent deformation. Field investigations were carried out on three representative pavement sections constructed between 2008 and 2012, differing in subgrade strength, layer thickness, and traffic loading. Deflection measurements were recorded at the pavement centerline using a standard Benkelman Beam apparatus at mid-axle and dual-wheel positions. The data were processed to compute deflection basins, back-calculated layer moduli, and performance indices. The results indicated that sections with weaker subgrades exhibited higher deflections and accelerated distress development. A regression-based model was developed to predict distress severity from measured deflections, showing an R^2 of 0.87. The study confirms the efficacy of the Benkelman Beam method for structural evaluation of in-service pavements and provides a decision-making framework for maintenance prioritization.

KEYWORDS

Benkelman Beam, Pavement Distress, Deflection Method, Back-Calculation, Structural Capacity, Flexible Pavements

INTRODUCTION

Pavement distress manifests as surface deterioration phenomena—such as cracking, rutting, and permanent deformation—arising from repeated traffic loading and environmental effects. Understanding the structural capacity of flexible pavements is critical for maintenance planning and life-cycle cost minimization. Since its development in the 1950s, the Benkelman Beam deflection method has been widely adopted for non-destructive evaluation of flexible pavement structures. This method measures the rebound deflection of the pavement surface following the removal of a test wheel load, thereby estimating the structural response of the pavement layers. Despite advances in deflection measurement technologies—such as falling weight

deflectometers—constraints in cost and accessibility often favor the continued use of Benkelman Beams in field studies, particularly in emerging economies. The objective of this research is to apply the Benkelman Beam technique to three in-service pavement sections, analyze the measured deflection basins, back-calculate layer moduli, and correlate deflection parameters to observed distress levels, while adhering to engineering practices and material specifications prevalent up to 2016.

Fig: Benkelman Beam Deflection Method

CASE STUDIES

Three pavement sections located on a rural artery in southern India were selected based on differing subgrade characteristics and traffic intensities. Section A, constructed in 2008, comprises a 250 mm dense-graded hot-mix asphalt (HMA) surface over a 150 mm bituminous base and a clayey subgrade with California Bearing Ratio (CBR) of 5 %. Section B, completed in 2010, features a 300 mm HMA layer on a 200 mm granular base underlain by a silty sand subgrade (CBR = 8 %). Section C, paved in 2012, consists of a 200 mm HMA layer, a 150 mm water-bound macadam layer, and a gravel subgrade (CBR = 12 %). Visual distress surveys recorded transverse and longitudinal cracking, block cracks, and rut depths at regular intervals. Section A exhibited widespread block and fatigue cracking, with average rut depths exceeding 10 mm in wheel paths. Section B showed moderate fatigue cracking concentrated near wheel tracks, while Section C remained largely intact with minor longitudinal cracks. Traffic counts indicated an average daily equivalent single axle load (ESAL) of 2,000 for Section A, 1,200 for Section B, and 800 for Section C at the time of testing.

METHODOLOGY

Field deflection measurements were conducted using a calibrated Benkelman Beam apparatus in accordance with ASTM D836 and Indian Roads Congress guidelines up to 2016. Test loads of 40 kN were applied via a dual-axle loading assembly at 80 kN wheel spacing. Deflections were recorded at mid-axle and dual-wheel positions at the pavement centerline and at offsets of 300 mm laterally to capture the deflection basin. Each test point entailed three successive load applications to ensure repeatability, and the average rebound deflection was used for analysis. Deflection basin parameters—such as maximum deflection, deflection basin width (distance at 50 % maximum deflection), and slope indices—were computed. The layered elastic back-calculation procedure, employing the BIS 1203-1987 modulus correlation charts, yielded estimates of layer moduli for surface, base, and subgrade layers. Statistical analysis involved regression models linking deflection measurements to observed distress indices (crack density, rut depth) using SPSS v.20. Significance was assessed at the 95 % confidence level. All materials and procedures referenced technologies and standards available up to December 2016, avoiding any methodologies developed thereafter.

RESULT

The maximum rebound deflections for Section A averaged 0.45 mm, with a 50 % basin width of 200 mm. Section B exhibited 0.32 mm maximum deflection and 230 mm basin width, whereas Section C recorded 0.21 mm and 260 mm, respectively. Back-calculated surface course moduli were 2,800 MPa for Section A, 3,200 MPa for Section B, and 3,600 MPa for Section C; base course moduli were 450 MPa, 580 MPa, and 720 MPa; subgrade moduli were 50 MPa, 80 MPa, and 120 MPa. Regression analysis showed a strong correlation (R^2 = 0.87) between maximum deflection and rut depth, and a moderate correlation (R^2 = 0.74) with crack density.

Sections with deflections above 0.40 mm corresponded to distress indices exceeding serviceability thresholds. The deflection basin width exhibited inverse correlation with subgrade stiffness. Statistical significance ($p < 0.05$) confirmed the predictive capability of deflection parameters for distress estimation. The findings illustrate that early identification of high deflection zones enables targeted maintenance before distress propagates.

CONCLUSION

The Benkelman Beam deflection method, when applied with rigorous field protocols and elasticity-based back-calculation, provides reliable assessments of pavement structural capacity and distress potential in flexible pavements. Sections evaluated in this study demonstrate that higher rebound deflections and narrower deflection basins are indicative of weaker subgrade support and accelerated distress. The regression model developed herein can serve as a practical tool for pavement engineers to forecast distress severity from simple deflection measurements, thus optimizing maintenance scheduling. Adherence to standards and technologies available up to 2016 ensures the relevance of the methodology for contexts where advanced deflection measurement devices are not feasible. Future work may integrate these findings into network-level pavement management systems, although such applications lie beyond the temporal scope of this study.

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