Kansas Department of Transportation

TECHNICAL SUMMARY

Non-Cantilever Fatigue Remaining-Life Simulation Software Using Probabilistic Wind Model for All Counties in Kansas

Report Number: KS-25-01 ▪ Publication Date: October 2025

Khalid W. Al Shboul, Ph.D.
Hayder A. Rasheed, Ph.D., P.E.

Kansas State University Transportation Center

Introduction

Full-span overhead sign support structures are critical ancillary systems that help guide drivers via a set of mounted highway signs. Cantilever and butterfly structures are also commonly utilized along major highways throughout the United States. Functionally, highway sign structures must support large truss spans so roadway users can acquire essential highway information and be alerted to possible hazards without sign obstructions in the travel path. Due to their long spans and their utilization of hollow circular tubes with a relatively small mass, these structures are semi-rigid with a low natural frequency and damping ratio (Arabi et al., 2018; Kacin et al., 2010; Li et al., 2005). As a result, they experience fatigue failure due to various fatigue loading scenarios, such as natural wind gust, galloping, vortex shedding, and truck-induced vibrations (Hosch & Fouad, 2010).

Project Description

Full-span overhead sign support structures are critical ancillary systems that use a set of mounted highway signs to guide drivers. The Kansas Department of Transportation (KDOT) also utilizes cantilevered and butterfly structures in their transportation system. A frequent comprehensive evaluation of full-span overhead sign support structures is essential to prevent possible hazards that may result from fatigue damage. However, the inspection accuracy of these structures depends on accurate quantification of wind-loading scenarios that structures may experience during their lifetimes. Therefore, this project sought to develop a detailed spatial wind-speed interpolation using finite element shape functions to provide wind-speed records for all counties in Kansas and derive daily wind-time profiles for a 45-year period (1975–2019). Another objective was to conduct rainflow analysis of the time histories to describe a wind-loading scenario in terms of the number of cycles. Overall, this study intended to ensure the resulting wind-speed data set is projectable into the future by mirroring the data about end of December 2019 / beginning of January 2020 timeline.

Project Results

This study used finite element shape functions to conduct spatial interpolation of wind-speed records for all Kansas counties (Al Shboul et al., 2023). This method considered spatial correlations among boundary sites. Artificial wind-time histories were constructed for each day for the entire 45-year study period, and the number of cycles developed using rainflow analysis was used to provide descriptive wind loading for civil engineering applications. User-friendly software was developed using C# to extrapolate wind-speed cycles for any future year. The following conclusions and findings were drawn from this study:

- The finite element spatial interpolation technique accurately estimates spatially continuous phenomena from measured values at limited sample points.
- Adequate care should be given during the meshing of the study area in terms of the element size since this method is highly spatially dependent.
- The global trend of predicted values in Sedgwick County captured the measured values and continued to commit relatively high peak wind-speed values for the year 1990 and low values in years 2000 and 2005.
- The number of cycles resulting from the rainflow analysis for the developed time histories was less than the number of cycles previously determined by the deterministic approach at Kansas State University, which was conservatively assumed to include dynamic amplification effects.

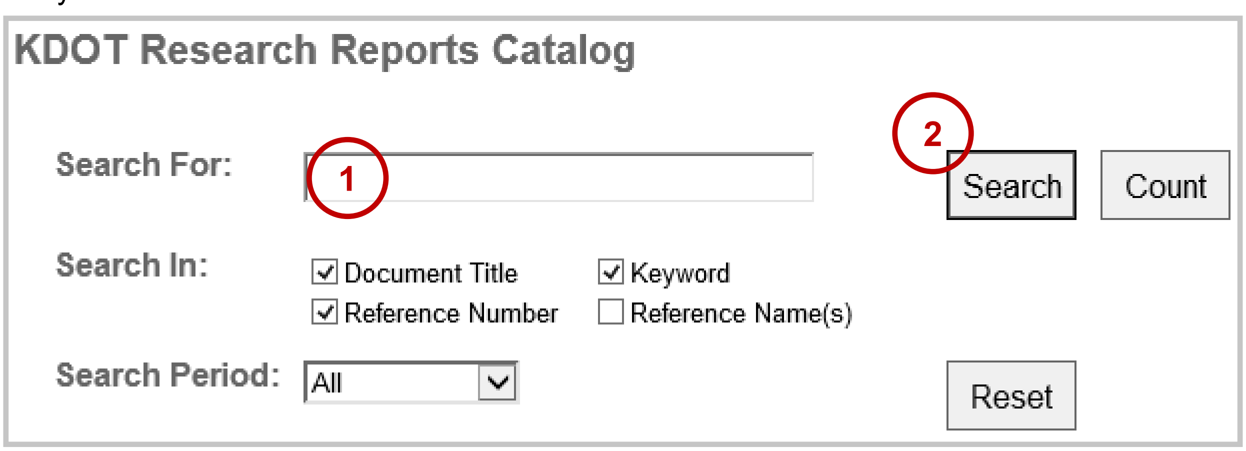
Project Information

For information on this report, please contact Hayder A. Rasheed, Ph.D., P.E., Kansas State University, 2126 Fiedler Hall, 1701C Platt St., Manhattan, KS 66506; 785-532-5862; hayder@k-state.edu.

Directions for Downloading the Full Report

To download the full report, visit https://kdotapp.ksdot.org/kdotlib/kdotlib2.aspx and do the following:

1. Enter KS-25-01 in the search box.
2. Click the Search button to the right of the search box.
3. You may have to scroll to find the specific report.
4. To download the report, click on the title of the report to open the PDF file and save it to your hard drive.



If you have any questions, please email us at KDOT#Research.Library@ks.gov.