

# Initial Analytical Investigation of Cantilever and Butterfly Steel Overhead Sign Trusses with Respect to Remaining Fatigue Life

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## Introduction

Fatigue failure of highway sign structures due to sustained wind-loading events has been recognized in many states. In fact, the American Association of State Highway and Transportation Officials specifies that the structural component should be designed for infinite life by maintaining wind-induced stress below their constant amplitude fatigue threshold. However, because existing structures are typically not designed for fatigue, the condition of all critical and fatigue-prone components must be evaluated for safety. Visual inspection requires extensive time and effort and may not detect unnoticed fatigue cracks, so growing attention has focused on analytical inspection tools to examine all critical members and connections for remaining fatigue life to ensure public safety. The reliability of these analytical tools depends on the accuracy of wind-loading models applied during the life span of the structure. This study devised a fill-interpolate-extend approach to furnish a wind-loading data ensemble for the duration of analysis. The ensemble established a reliable synthetic wind model to generate fatigue cycle counts. In addition, a comprehensive analytical framework, including structural modeling, stress extraction/processing, and fatigue damage simulation, was integrated to yield an affordable tool that is applicable to various sign structures topologies. The resulting software for non-cantilever overhead structures as well as cantilever and butterfly assemblies were successfully verified to predict real cases for fatigue damage, reflecting the in-situ condition of the structures.

## Project Description

Low-cost cantilevered and butterfly sign support structures are commonly used because they more effectively reduce the probability of vehicle collision compared to overhead sign structures. Over time, the span of cantilevered support structures has increased as safety concerns have caused the upright component of the structures to be installed further from the road, see Figure 1.1–1.2. However, because these structures are typically used for multi-lane roads, the structures are increasingly susceptible to large amplitude oscillations from various wind-loading scenarios. Therefore, this study evaluated the remaining fatigue life of cantilevered and butterfly structures to build a comprehensive tool to accurately predict the remaining fatigue life of cantilevered and butterfly highway sign support structures subjected to prolonged and sustained wind fluctuations. The analytical study sought to obtain the following specified objectives:

- Develop fatigue analysis procedures to estimate the fatigue life expectancy of cantilevered and butterfly sign structures and evaluate the remaining fatigue life of these structures based on the wind-loading dataset generated above.
- Identify and mark the most critical members in the various sign structures for further field investigation concerning fatigue life consumption.
- Project the number of years these structures would experience total fatigue damage and guide highway agencies to prioritize their inspection plans.
- Develop a computationally affordable simulation package using object-oriented programming language C# to interact with the FE software STAAD Pro to predict fatigue life.

## Project Results

This study developed and implemented a framework for analytical fatigue damage evaluation in computer software to provide a cost-effective inspection tool to assess highway sign structures. Analytical models were created for a cantilever structure based on wind-event history to simulate damage in various critical truss components. The software showed its superior capability in calculating fatigue damage by capturing a crack in the mast connection. The main conclusion is that the most critical fatigue detail is the connection because it has lower CAFT and is susceptible to high stress.

KDOT standards recommend replacing the gusseted box connection with the ring-stiffened connection due to the superior resistance of the latter to fatigue damage. Accurate fatigue damage characterization is highly dependent on actual past wind events during the service life of the structure. Fatigue failure has been widely noticed in flexible highway sign structures, and it is essential to alert highway agencies to faulty connections in an efficient and timely manner. Therefore, this developed software should beneficially impact state highway decision-making and the development of inspection inventories.

## Project Information

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