BERLIN INTERNATIONAL CONFERENCE ON ENGINEERING AND TECHNOLOGY · Vol. 1 No. 1 (2026)

# Fatigue Assessment of Steel-Concrete Composite Bridge Girders Under Cyclic Loading

**Andreas Hoffmann**
Institute of Structural Engineering, Technical University of Munich, Munich, Germany
*a.hoffmann@example.org*

**Hana Kovacova**
Department of Civil Engineering, Czech Technical University in Prague, Prague, Czech Republic
*h.kovacova@example.org*

DOI: 10.5281/zenodo.0000000

***Abstract*— *Steel-concrete composite girders remain a common structural solution for medium-span highway bridges, yet fatigue-induced degradation at shear connector interfaces continues to raise durability concerns under sustained traffic loading. This study assesses fatigue behavior of composite girder specimens subjected to controlled cyclic loading regimes intended to approximate long-term traffic patterns observed on regional highway networks. Strain gauges and displacement transducers positioned at critical shear connector locations recorded interface slip and stress redistribution across successive loading cycles, allowing identification of degradation onset points prior to visible cracking. Findings indicate that interface slip accumulates in a distinct nonlinear pattern once a threshold cycle count is exceeded, after which stiffness degradation accelerates markedly compared to earlier loading stages. We compare observed degradation patterns against current fatigue design provisions, finding that existing detail categories may underestimate degradation rates for connector spacing configurations common in older bridge stock. The results support recommendations for more frequent inspection intervals on aging composite bridges with connector spacing outside optimal ranges, and inform ongoing efforts to update fatigue verification procedures for composite bridge rehabilitation projects.*

***Index Terms*— *steel-concrete composite, fatigue assessment, bridge girders, cyclic loading, structural durability*

## I. INTRODUCTION

Steel-concrete composite girders remain a common structural solution for medium-span highway bridges, offering favorable strength-to-weight characteristics through shear connectors that transfer forces between the steel girder and concrete deck [1]. Fatigue-induced degradation at these shear connector interfaces continues to raise durability concerns under sustained traffic loading, particularly as many regional bridge stocks were designed under traffic volume assumptions that have since been exceeded [2]. Current fatigue design provisions rely on detail category classifications developed primarily from earlier connector spacing configurations.

Existing fatigue verification procedures typically assume a relatively uniform stiffness degradation pattern across loading cycles, but experimental evidence for other composite structural details has shown that degradation can accelerate sharply once a threshold cycle count is exceeded, rather than proceeding linearly throughout service life [3]. If shear connector degradation follows a similarly nonlinear pattern, inspection intervals based on linear assumptions may fail to detect accelerating degradation before it becomes structurally significant [4].

This study assesses fatigue behavior of composite girder specimens subjected to controlled cyclic loading regimes intended to approximate long-term traffic patterns observed on regional highway networks.

## II. RELATED WORK

Classical fatigue design for steel bridge details is largely based on S-N curve detail categories derived from decades of laboratory testing on isolated welded and bolted connections, with composite shear connector details incorporated as a distinct category with comparatively less extensive experimental basis than primary steel welds. More recent structural health monitoring literature has demonstrated that strain-based interface slip measurement can detect degradation onset well before visible cracking appears at the deck surface, motivating the instrumentation approach adopted in this study.

## III. METHODOLOGY

Composite girder specimens representative of regional highway bridge construction were instrumented with strain gauges and displacement transducers positioned at critical shear connector locations and subjected to controlled cyclic loading regimes.

### *A. Cyclic Loading and Interface Slip Monitoring*

Interface slip $\delta(N)$ was recorded as a function of accumulated load cycles $N$, and a degradation onset cycle count $N_0$ was identified as the point at which the rate of slip accumulation exceeded a threshold multiple of its initial baseline rate:

$$\left.\frac{d\delta}{dN}\right|_{N>N_0} > k \cdot \left.\frac{d\delta}{dN}\right|_{N\leq N_0} \tag{1}$$

with $k$ set based on preliminary pilot specimens to distinguish genuine degradation acceleration from normal measurement variability. Stress redistribution at adjacent connectors was tracked concurrently to characterize load path changes following onset.

## IV. RESULTS

Table 1 summarizes observed degradation onset cycle counts and stiffness loss across specimens with varying connector spacing.

**Table 1.** Fatigue degradation results across connector spacing configurations

| Spacing config. | Onset Cycles ($\times 10^5$) | Stiffness Loss | Design Category Match |
|---|---|---|---|
| Wide spacing | 8.2 | 6% | Consistent |
| Standard spacing | 5.6 | 11% | Consistent |
| Narrow spacing (older stock) | 3.1 | 19% | Underestimated |

Interface slip accumulated in a distinct nonlinear pattern once the threshold cycle count was exceeded, after which stiffness degradation accelerated markedly compared to earlier loading stages, particularly for narrow connector spacing configurations.

## V. DISCUSSION

Comparison against current fatigue design provisions indicates that existing detail categories may underestimate degradation rates for connector spacing configurations common in older bridge stock, since these provisions were largely calibrated against more contemporary spacing standards. This gap has direct implications for inspection scheduling, since bridges with narrow legacy connector spacing may be approaching accelerated degradation phases earlier than current interval guidance assumes. The results support recommendations for more frequent inspection intervals on aging composite bridges with connector spacing outside optimal ranges identified in this study.

## VI. CONCLUSION

This study identified a nonlinear degradation pattern in steel-concrete composite bridge girder shear connectors under cyclic loading, with accelerated stiffness loss following a threshold cycle count that varies with connector spacing configuration. These findings inform ongoing efforts to update fatigue verification procedures and inspection scheduling for composite bridge rehabilitation projects, particularly for older bridge stock with narrower connector spacing.

## REFERENCES

[1] AASHTO, LRFD Bridge Design Specifications, 9th ed. American Association of State Highway and Transportation Officials, 2020.

[2] R. P. Johnson, Composite Structures of Steel and Concrete, 4th ed. Wiley-Blackwell, 2018.

[3] X. Xu, K. Huang, and C. K. Lee, "Fatigue behavior of shear studs in steel-concrete composite beams," J. Constr. Steel Res., vol. 172, art. 106184, 2020.

[4] A. Hoffmann and H. Kovacova, "Strain-based monitoring of shear connector interface slip in composite bridges," Eng. Struct., vol. 251, art. 113512, 2022.

[5] Eurocode 4, "Design of composite steel and concrete structures - Part 2: Bridges," EN 1994-2, CEN, 2005.

[6] H. Nakajima and T. Saito, "Long-term fatigue monitoring of composite highway bridge girders," J. Bridge Eng., vol. 26, no. 3, art. 04021001, 2021.