NCHRP 12-92

Proposed LRFD Bridge Design Specifications for Light Rail Transit Loads

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Introduction
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The objectives of NCHRP 12-92 are:

• To characterize light rail transit load effects on the behavior of bridge superstructure (e.g., standard train load, dynamic load allowance, load distribution, and design factors for LRFD)

• To examine the interaction between the light rail load and supporting structures, which can generate various forces to consider in design and practice

• To propose a unified design approach for light rail transit and highway traffic, and corresponding design articles and commentaries for the AASHTO LRFD Specifications, including design examples for practitioners
Introduction

Overview of Research

Phase I (Planning)
- Literature review
- Proposal of research methodology
- Description of alternative specifications
- Interim report 1 **Completed**

Phase II (Methodology)
- Refined FE analysis
- Standard light rail train load model
- Load effects and forces
- Interim report 2 **To be completed in July 2015**

Phase III (Specifications)
- Proposal of design articles
- Development of design examples
- Interim report 3

Phase IV (Final products)
- Update of specifications
- Ballot items
- Final report
Introduction

Research Tasks

- Task 1: A critical literature review
- Task 2: A methodology specifying the light rail transit load characteristics
- Task 3: A detailed outline with annotated description for the developed specifications
- Task 4: Preparation of interim report No. 1
- Task 5: Execution of the approved work to develop the proposed methodology (we are here now)
- Task 6: Preparation of interim report No. 2
- Task 7: Development of proposed AASHTO LRFD design specifications and commentary
- Task 8: Development of design examples
- Task 9: Preparation of interim report No. 3
- Task 10: Update of proposed development to the AASHTO LRFD Specifications
- Task 11: Preparation of a final report
Field Testing
Field Testing

Strain gage calibration to measure train load

Empty train (laboratory)

Empty train (site)

Wheel load distribution

Five light rail bridges in Denver

Broadway Bridge

Typical girder strain
Finite Element Modeling
Finite Element Modeling

Validation of Modeling Approach (5 bridges in Denver, CO)

Indiana Bridge

Two articulated trains on Indiana Bridge

Live load distribution

Dynamic response
Design of Benchmark Bridges

Steel plate girder

Steel box girder

PC I girder

PC box girder

RC girder girder
Finite Element Modeling

Modeling of Benchmark Bridges (5 types)

• Response monitoring: 3828 static/dynamic models (116 models for HL93 and 3,712 models for light rail trains)

Four representative light rail trains (MN, UT, MA, and CO)
Finite Element Modeling

Modeling of Benchmark Bridges (flexural moment)

Typical maximum moment
(Steel plate girder bridges)

Light rail trains vs. HL-93
(Steel plate girder bridges)
Finite Element Modeling

Modeling of Benchmark Bridges (serviceability)

Deflection requirements
(Prestressed concrete I girder bridges)

Passenger comfort criteria
(Prestressed concrete I girder bridges)
Finite Element Modeling

Modeling of Benchmark Bridges (dynamic load allowance)

Dynamic load allowance

Mean DLA (simply-supported span)

Mean DLA (multiple span)

DLA = 25% suggested for light rail trains
(2960 FE models and associated probability-based inference)

Probability-based inference

512 load cases
33% in AASHTO LRFD

512 load cases

75-year
99.9%
90.0%

Inv. standard normal distribution

y = 0.4183x - 1.7189
R² = 0.9733

DLA (%) - Steel Plate

PC Box  PC I  ST Box  ST Plate  RC

Average  90%  99.9%  75-year

PC Box  PC I  ST Box  ST Plate  RC

Average  90%  99.9%  75-year
Finite Element Modeling

Standard live load model for light rail transit (development)

46,400 load cases analyzed

- Decomposition of lane and concentrated loads
- Probability-based load inference

Proposed load configuration

Comparison to HL-93
Finite Element Modeling

Standard live load model for light rail transit (assessment)

**Bending moment**

Site-based inference vs. candidate load model

**Shear force**

Proposed standard live load model

Alternative live load models
Summary
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● The behavior of five light rail bridges was examined on site: modeling approach validated and statistical properties acquired

● Five benchmark bridges were designed and modeled: 3828 static/dynamic models were used (simply-supported and multiple spans)

● Dynamic load allowance was proposed to be 25% based on 2960 load cases and four risk levels

● A standard live load model was proposed and assessed against site-based load inference and existing light rail train loads
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