University of Massachusetts Lowell
Department of Civil and Environmental Engineering
Team #1: Ana Gouveia, Sarah Shaw, Thomas Duval, Anas Alsaied, Chen Sun
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TABLE OF CONTENTS

ABSTRACT 3

BRIDGE DESIGN INTRODUCTION 3

HIGHWAY & BRIDGE GEOMETRY 4

GEOTECHNICAL ENGINEERING 4

ABUTMENT DESIGN 5

REINFORCED CONCRETE DESIGN 6

SUPERSTRUCTURE DESIGN 6

DRAINAGE AND EROSION CONTROL 7

ENVIRONMENTAL PERMITTING 7

CONSTRUCTION ESTIMATE 7

MASSDOT SCOPE AND FEE 7

CONCLUSION 8

APPENDIX A – SAMPLE CALCULATIONS 1

APPENDIX B – DOCUMENTS 1

APPENDIX C – CAD DRAWINGS 1

APPENDIX D – PREVIOUS REPORTS 1

ABSTRACT

The purpose of this capstone design project is to design the superstructure elements of the Brimfield/Palmer replacement bridge, which carries Kings Bridge Road over the Quaboag River. The project consists of replacing the existing single-span bridge with a new 170-foot single-span interior girder bridge, with a 100-year flood clearance of 2 feet.

All design is in accordance with the 6th Edition of AASHTO LRFD Bridge Design Specifications 2012, the 1st Edition of AASHTO Guide Specifications for LRFD Seismic Bridge Design 2009, and the Massachusetts Department of Transportation (MassDOT) LRFD Bridge Manual (2009) Part I and II. All steel design was designed by the Load and Resistance Factor Design Method (LRFD).

An overview of the overall design conditions and work was performed in Module 1: Bridge Design Introduction. The bridge geometry used consists of: 4 Lanes at 12’-0”, 2 Shoulder/Bicycle Lanes at 10’-0”, 2 Sidewalks at 8’-0” and S3-PL2 Bridge Rail. Dead design loads were determined as directed by codes, live load was determined for HL93 truck loading, wind and seismic loads were not calculated. Concrete and Steel were used according to specifications. All values used for loads and materials can be found on the Design Task Protocol produced within the respective module.

BRIDGE DESIGN INTRODUCTION

An overview of the overall design work to be performed was performed in Module 1: Bridge Design Introduction. After determining the project constraints, roadway type, user needs, span arrangement, subsurface material and foundation and superstructure type and environmental issues, a Design Task Protocol was produced (see Appendix B, page B-1).

The Bridge Design Criteria was determined as follows:

- Bridge Span: 170-ft between abutments centerlines.
- Bridge Cross-Section: A total of 86’-9” between edges composed of -
  - 4 Lanes @ 12’-0”
  - 2 Shoulder/Bicycle Lanes @ 10’-0”
  - 2 Sidewalks @ 8’-0”

S3-PL2 Bridge Rail

- Superstructure to be made of Single Span Composite Steel Plate Girder with Reinforced Concrete Deck.
- Strip Abutments Designed based on thermal movement and to hold an Expansion Joint type .
- Materials to be used: concrete and steel.
- Dead design loads were determined as directed by codes, live load was determined for HL93 truck loading, wind and seismic loads were not calculated.

HIGHWAY & BRIDGE GEOMETRY

For module 2: Highway & Bridge Geometry, AutoCAD plan, elevation, section and detail drawings were produced for the bridge. In order to obtain the drawings, it was necessary to define the abutment geometry, determine abutment backwall and expansion joint type based on thermal movement, determine bridge slope across the span and of the bridge cross-section.

The abutment geometry was defined as:

- Depth of soil above front of abutment: 5 ft.
- Footing Width: 15 ft (Calculated from 0.67*H rounded to up to the nearest half foot)
- Footing Thickness: 2.5 ft
- Footing Toe: 2 ft
- Thermal expansion was determined using:
- Expansion joint used

Further, an existing surveying map of the area was incorporated to the drawings. AutoCAD drawings were obtained from MassDOT’s website and adapted to the current bridge. The drawings produced are attached to this report, please see Appendix C, pages B-2 to B-3. Plan view, page B-2. Elevation and section, page B-3.

GEOTECHNICAL ENGINEERING

Module 3 was dedicated to geotechnical engineering. Soil borings were analyzed in order to produce a geotechnical report. Settlement and bearing pressure calculations were also done.

Sections 10 & 11 from the AASHTO LRFD Design specifications Fifth Ed. 2010 were used in order to design the bridge foundations and abutment.

In order to determine settlement and bearing pressure, Boring No. B-2 was used (refer to page) to obtain SPT ($N_{MEASURED}$) values. These ($N_{MEASURED}$) were corrected for the appropriate amount of energy ratio due to the equipment, borehole diameter, sampling method, rod length, and further normalized for the overburden due to deeper depths with the use of Equation (1) from AASHTO (2010) Equation 10.4.6.2.4-1. Given the overburden correction, it was possible to obtain C_N, which through Bowles 1996 offered a correlation to obtain the effective friction angle of the local soil. The friction angle obtained was equal to 33.2 degrees.

The bearing resistance of soil was obtained using equation (1) - from AASHTO (2010) Equation 10.6.3.1.2a-1. The shape factors and areas used were applied according to Meyerhoff's method. The bearing capacity obtained was equal to 16.18 ksf.

$$qn = y.Df.Nqm.Cwq + .5.y.B'.Nym.Cwy \quad (1)$$

The settlement analysis only observed its elastic component, and was determined using equation (2) – from AASHTO (2010) Equation 10.6.2.4.2-1. The serviceability allowed in the design was equal of 1 in, and that allowed the computation of the allowable stress for the abutment. The allowable stress obtained was equal to qo = 10.93 ksf.

$$Se = [q0*(1-v^2)\sqrt{A'}]/ [144*(Es\beta z)] \quad (2)$$

ABUTMENT DESIGN

From the values of settlement and bearing pressures previously computed in module 3, footing size as specified in module 2, a spreadsheet was written to compute bearing pressures for the abutment design.

Load cases used for the design were Strength 1 Min. and Service 1 Load Combinations. The footing dimensions used were equal to:

Abutment Height = 22'0"

Stem Thickness = 4'6"

Footing Width = 15’0”

Toe Width = 2’0”

Footing Thickness = 2’6”

In order to design the abutment, it was first necessary to compute the loads on it. Dead loads were split in DW and DC per AASHTO standard. In order to calculate the live load, a lane load of 640 plf and a reaction based on the maximum shear due to an HL-93 truck were used. The live load was further factored using a multi-presence factor equal to m=0.65, as instructed on AASHTO Table 3.6.1.1.2-1. The superstructure dead load DL – DC was obtained equal to 1500.00 kips. The superstructure DL – DW was obtained equal to 108.38 kips and superstructure live load was obtained as equal to 400.0 kips.

The load values and footing dimensions obtained were further imported to an excel spreadsheet and these were used to determine vertical loads, lateral forces and resisting overturning moments on abutment and on the stem. The values obtained were then factored using limit states Strength I-min and Service-I.

These results were then used to determine stability, eccentricity, safety criteria, bearing and sliding check. The abutment eccentricity was within design limits. The bearing capacity obtained was equal to 5.51 and 5.41 ksf, for limit states strength I-min, and service-I respectively, both values were smaller than the ultimate value allowed in the design, satisfying design conditions.

REINFORCED CONCRETE DESIGN

Given the previos settlement and bearing pressure values computed, and footing dimensions given, footing, abutment stem and backwall reinforcement was determined.

SUPERSTRUCTURE DESIGN

An overview of the overall design work to be performed was performed in Module 1: Bridge Design Introduction. After determining the project constraints, roadway type, user needs, span arrangement, subsurface material and foundation and superstructure type and environmental issues, a Design Task Protocol was produced (see Appendix B, page B-1).

The Bridge Design Criteria was determined as follows:

DRAINAGE AND EROSION CONTROL

An overview of the overall design work to be performed was performed in Module 1: Bridge Design Introduction. After determining the project constraints, roadway type, user needs, span arrangement, subsurface material and foundation and superstructure type and environmental issues, a Design Task Protocol was produced (see Appendix B, page B-1).

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ENVIRONMENTAL PERMITTING

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CONSTRUCTION ESTIMATE

An overview of the overall design work to be performed was performed in Module 1: Bridge Design Introduction. After determining the project constraints, roadway type, user needs, span arrangement, subsurface material and foundation and superstructure type and environmental issues, a Design Task Protocol was produced (see Appendix B, page B-1).

The Bridge Design Criteria was determined as follows:

MASSDOT SCOPE AND FEE

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CONCLUSION

An overview of the overall design work to be performed was performed in Module 1: Bridge Design Introduction. After determining the project constraints, roadway type, user needs, span arrangement, subsurface material and foundation and superstructure type and environmental issues, a Design Task Protocol was produced (see Appendix B, page B-1).

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