

CHAPTER 1

INTRODUCTION

1.1 Background

The decline of the United States' infrastructure has never been more prevalent than it is today. The essential lifelines of society, such as water and highway systems, that were constructed decades ago are deteriorating. The waning quality of the infrastructure results in numerous problems for individuals, businesses, the economy, and the United States as a whole. In particular, the highway system is a vital link in the United States, and its bridges have been victimized by age and weathering over the past two decades.

Studies have shown that over 30 percent of the bridges in the United States are structurally deficient, and/or over 50 years old. The majority of the highway bridges have reinforced concrete decks supported on steel or concrete girders. Concrete has long been the choice of designers for highway bridge decks, and over the years the weather has taken its toll on reinforced concrete decks. Rainwater and deicing chemicals applied to roadway surfaces during the winter months have seeped through many concrete decks and caused corrosion of the reinforcing steel. The expansion of the reinforcing steel from corrosion and other factors, such as freeze-thaw cycling, have caused spalling of the concrete surrounding the steel reinforcement in decks. Deterioration of reinforced concrete decks has resulted in lane closures, reduced bridge capacities, and often entire closures of bridges.

The dilemma involving repair or replacement of deteriorated reinforced concrete decks is apparent. Repairing a partly deteriorated concrete deck will only serve to partially remedy the situation. Other areas of the deck will be as likely to deteriorate and will eventually require repair. If replacing the entire deck is in order, then using a reinforced concrete deck a second time may be illogical and impossible. Reinforced concrete decks require considerable time to be constructed (i.e., formwork placement and concrete curing) which would result in extended highway closure time. In addition,

typical reinforced concrete bridge decks are very heavy and can weigh over 100 lb/ft² of deck area. The large dead load from a reinforced concrete bridge deck may make retrofitting to meet current design specifications while retaining the remaining superstructure and substructure impossible or not feasible. Thus, alternative approaches are required to remedy these situations.

In response to the problems stated above, Reynolds Aluminum Company, with assistance from High Steel Structures, Inc. of Lancaster, PA, the Virginia Department of Transportation (VDOT), and the Federal Highway Administration's (FHWA) Turner-Fairbanks Highway Research Center has researched and developed an aluminum isotropic bridge deck system known as ALUMADECK™ (Reynolds Metals Company 1997). ALUMADECK is designed to be a viable and feasible system for bridge deck retrofitting, replacement, and construction.

1.2 General Bridge Behavior

The response of bridges to dynamic vehicular loading is important to bridge evaluation. A bridge's strength, rating, and serviceability depend on the manner upon which the bridge behaves under dynamic loading. Analytical models can determine theoretical behavior, but the actual behavior of a bridge may be quite different from the manner that it was designed. Actual in-service testing of new and old bridges is beneficial for evaluating strength and serviceability characteristics of a bridge and for determining the effectiveness of design specification approaches. Commonly, the actual load distribution characteristics and dynamic amplification of responses (i.e., stresses and deflections) in a bridge are studied.

In a typical highway bridge, the load distribution behavior involves the distribution of load amongst the longitudinal supporting members of the bridge system. Considerable research has been completed on the more common types of bridges (i.e., bridges with reinforced concrete decks on steel or concrete girders), and the results have been used to validate and determine simplified equations for inclusion in bridge design

specifications. An accurate estimate of the distribution of load in a bridge allows for the development of more efficient and reliable bridge design codes.

The dynamic amplification of responses is also important for determining a bridge's strength, serviceability, and rating. The increase in response caused by moving vehicular loads as compared to statically applied loads has to be included in the design and evaluation processes. The approach common to most specifications is to account for the dynamic effect by increasing the static response by an amplification factor. However, studies conducted on the more common types of bridge systems have shown that a distinct amplification factor is hard to obtain. The effects of impact on a bridge can serve to greatly reduce the load carrying capacity of a bridge, and can cause overstress in particular bridge components.

Accurate estimations of the above parameters become increasingly important as larger legal and permit loads are allowed on the highways. In addition, as composites and other materials such as aluminum become more prevalent in bridges, there is an expanding need for design specifications and field testing that address these materials in bridge use.

1.3 Research Involvement

This research is a single part of a larger research effort conducted by the Virginia Transportation Research Council (VTRC) under FHWA sponsorship. VTRC developed a three-phase study of the ALUMADECK system.

Phase 1 involved a set of extensive laboratory tests on individual aluminum deck panels. According to Matteo (1997; Matteo et al 1996), the panels were subjected to a series of elastic loads (i.e., stresses below the yield stress) and eventually tests to failure under simulated truck wheel-loads. The tests were intended to provide data to be compared to a finite element model and the "equivalent strip" model used in the American Association of State Highway and Transportation Officials (AASHTO) specifications to model System II behavior. System II behavior deals with bending of the deck between the longitudinal supports members. The intent was to develop a predictive

model to be used in future applications of the aluminum deck system. A brief review of the results is included in the literature review of Chapter 2.

Phase II of the study involves field-testing of an actual in service ALUMADECK system. This research thesis is a part of Phase II. At the time of this writing there are two bridges that employ the ALUMADECK system. The first bridge, the Corbin Bridge in Huntingdon, PA, incorporates the system into its 320-ft. single lane suspension bridge. The second bridge is located in Mecklenburg County, VA and spans the Little Buffalo Creek. The Little Buffalo Creek Bridge was instrumented and field-tested by VTRC under static and dynamic loads. The data collected from the field tests is evaluated in this research and will be used to provide a basis for Phase III of the study

Phase III will involve an evaluation of the long term structural and environmental behavior of the deck. The aluminum deck with the shop applied wearing surface will be laboratory tested to evaluate fatigue strength and durability of both the deck and wearing surface (Matteo 1997, Matteo et al 1996).

1.4 Objectives and Scope

As previously mentioned, this research is a field data evaluation from test truck loading of an in-service bridge that employs a particular version of the ALUMADECK system. The bridge is the Little Buffalo Creek Bridge located in Mecklenburg County, VA. All aspects of field testing for this research were performed solely by VTRC. Because this type of bridge system is relatively new, there is a demand for in-service testing under vehicular loading. In this research, the longitudinal supporting members are evaluated to determine their load distribution behavior, dynamic load allowances, and extent of composite action with the aluminum deck. In addition, various deck stresses that were developed during the tests are evaluated to provide insight on the fatigue behavior of the Little Buffalo Creek Bridge. The current specifications used for comparison throughout this research are the AASHTO Standard Specifications for Highway Bridges (AASHTO SSHB 1996) and the AASHTO LRFD Bridge Design Specifications (AASHTO LRFD 1994).

The load distribution behavior amongst the main longitudinal members is examined to determine the effects of truck position (i.e., transverse and longitudinal) on load distribution. In addition, distribution factors are determined from the available field data. The distribution factors from the field data are compared to the values from the design calculations provided by VDOT and to the previously mentioned AASHTO specifications. AASHTO SSHB (1996) and AASHTO LRFD (1994) do not specifically address this type of bridge system in regards to the use of empirical equations for determining distribution factors; however, the behavior between the supporting members is said to be similar to that of a reinforced concrete slab (Matteo 1997). Based on this similarity, the aluminum deck is assumed to behave similar to a concrete deck to allow for use of the simplified equations available in AASHTO SSHB (1996) and AASHTO LRFD (1994).

The dynamic amplifications of responses for the main longitudinal members are evaluated and the dynamic load allowances are calculated for various load cases. The dynamic load allowances are compared to the values from the design calculations and to the values from the previously mentioned AASHTO specifications.

The extent of composite action developed between the aluminum deck and longitudinal supporting members is examined for various static load cases. The aluminum deck was designed for full composite action with the girders. A linear strain distribution is assumed throughout the depth of the steel girders, and strain data from the top and bottom flanges is used to determine the location of the neutral axis within the girders. The results are compared to the theoretical full composite and non-composite neutral axis locations, and the extent of composite action present is evaluated.

The deck stresses developed are examined to provide insight on the fatigue strength of different detail categories within the deck. Strain data was collected from strain gauges placed at locations on the aluminum deck comprised of entirely base metal and at longitudinal groove-weld locations. The actual stress ranges are compared to the allowable fatigue stress ranges determined for the different detail categories. In addition,

the behavior of a longitudinal, mechanical deck splice detail is evaluated using gauges located in the vicinity of the splice.

The results from this research should provide valuable information concerning the behavior of this particular type of ALUMADECK system. The results should be beneficial in developing future laboratory and field tests of this and other ALUMADECK systems.