Research Problem Statement

Title

Instrumentation to aid in steel bridge fabrication pilot program

Problem Statement

There are many documented and undocumented cases of steel bridge erection problems. This is especially true for complex structures, such as curved girders and box structures. As an example, in 2001 the Virginia Department of Transportation was faced with a problem at the Magruder Boulevard over I-64 Bridge in Hampton, Virginia. Here an incorrectly fabricated girder was not identified until most of the structure was erected and some components did not fit together. This single incident resulted in millions of dollars in legal expenses, re-fabrication expenses, and delays in construction of the bridge. Because of these types of problems, most states require a steel bridge fabricator to shop assemble some or all parts of a steel bridge. This practice is intended to assure that the structure, primarily the splice plates and cross frames, will fit together at the job site as designed. This shop assembly procedure is labor and time-intensive and adds significant cost to a steel bridge. In addition, quality control data is typically taken by hand with string lines and rulers and recorded manually on paper reports. This process can sometimes contain errors (i.e. wrong number written down or errors in measurements) and does not provide a complete permanent record of a fabricated component.

This research will deliver a laser based bridge measurment system that will greatly improve the quality and reduce the cost of complex bridge fabricaton. This system will reduce or eliminate the need for shop fit-up and assembly by providing a virtual assembly capability using specialized solid modelling and analysis software specifically targeted at large-scale complex structures. This laser system will be specifically designed for steel bridge fabrication and will accurately and precisely measure all aspects of a bridge component, including splice hole locations, camber, sweep, and end-kick in a nearly full-automated manner. The completed system can be used as a quality control tool to document as-built conditions of girders and as a virtual fit-up tool to eliminate shop assembly. There is no existing laser-based measurement system that can measure very large and very complex girders with the accuracy, as rapidly, and with as little operator intervention as that being proposed.

The use of this laser system on just one complex bridge job could result in benefits that exceed the cost of this entire research project. The stakeholder group that can potentially benefit the most from the use of the proposed laser system are the State DOTs, who could save millions of dollars on the cost of steel bridges and receive greater quality assurance on the end product. Elimination of shop assembly of complex structures could save millions of dollars. The proposed system can identify fabrication errors at the fabrication shop allowing repairs to be made prior to painting and shipment to a job site. Documentation from the proposed system is a permanent record that is certifiable and traceable. This documentation can be used to help reduce construction claims and could serve as evidence in legal disputes in cases where there are problems during bridge erection. Avoiding the legal expenses from one such dispute of this type could more than pay for the cost of this research.

Emphasis Area

Steel bridge fabrication

Background

Because of the steel bridge erection problems noted above, research work began prior to 2000 with initial proof-of-concept testing on the virtual assembly of steel bridges at FHWA. The goal of the initial testing was to look at using a prototype FHWA laser system to measure splice hole locations in girders and measurements were made in a steel bridge shop assembly yard. These initial tests demonstrated the potential of the laser measurement system and showed that splice plates could be designed from measurements.

In 2007 an NCHRP-IDEA project continued development of this concept. A significantly more advanced laser system version was used for this project, several generations removed from the FHWA prototype used in 2000. This project included extensive laboratory tests to develop measurement procedures and measurements and testing were conducted at a steel bridge fabrication facility. These tests demonstrated the laser system can work in a fabrication shop environment and that measurements can be made directly on girders without any special targets. The virtual fit-up of straight girders was demonstrated. Measurements were made on typical straight and slightly curved girders. This project helped identify many of the steps necessary to integrate a measurement system at a fabricator. This NCHRP-IDEA project did not address complex structures, particularly virtual fit-up algorithms for these complex structures.

This research project extends prior research and focuses on the most important and economically beneficial application of the laser measurement system, large complex structures. Prior research demonstrated virtual fit-up of straight girders. While they are the most common fabricated girder type, straight girders do not represent the largest payoff. Some of the most complex structures to fabricate and erect are box and tub girders. Such structures are more efficient in torsion and are advantageous to use in many applications. However, these structures often have fit-up problems during erection and the required shop assembly of these structures is very expensive. Virtual assembly tools cannot only reduce or eliminate shop assembly expenses, but they could allow for the use of these bridge designs in circumstances previously considered impractical. Development of virtual fit-up analysis tools for complex structures is a very difficult problem and successful implementation would be a significant advancement in the steel bridge fabrication industry.

Scope of Work

Three phases are proposed for this research in order to proceed in an incremental and effectively managed fashion as well as to manage the risk of delivering an expensive system that is ready for full-scale implementation. Phase I will define measurement requirements on large-scale complex components and assess commercial software analysis tools. Phase II will extend this work to the development of virtual fit-up analysis tools for large-scale components, validated with testing in a fabrication plant. Phase III will incorporate the software tools developed in the previous phase and deliver a system at a fabricator. The Phase III project deliverable will be a dedicated laser-based bridge measurement system installed at a bridge fabricator or a group of fabricators. The final Phase III task will apply the laser measurement system to an actual complex structure bridge job, coordinated with a State DOT partner, where no shop assembly is employed.

Potential Implementation

The result of Phase I and II will be the development of the virtual fit-up software for complex structures, which is the key component needed for successful implementation. With this component in place, Phase III of the project will deliver a dedicated laser-based bridge measurement system installed at a bridge fabricator or shared among a group of fabricators. One of the most important aspects of successful implementation is a demonstration of system capabilities to the key stake-holders. As such the project will culminate in the demonstration of the system on an actual complex structure bridge job where no shop assembly is employed. All three Phases of the project will work directly with a steel bridge fabricator with the goal to produce a system that will integrate directly into existing fabrication shop environments.

Time / Cost Estimate

Phase I is estimated to require 6-months to complete and the result will be to define measurement requirements for large-scale components. Phase I has an estimated funding level of $150,000. Following the success of Phase I work will progress to Phase II. Phase II is estimated to require 12-months to complete and the result will be the development of large complex structure virtual fit-up software. Phase II has an estimated funding level of $200,000. If Phase II is successful, then an implementation plan will be created to carry out Phase III. The plan will present possible options for long-term implementation, such as where and how a final system will be deployed and where ownership of the system will reside. It will also present funding options (fully through research funds, private industry partnership, or other options) for Phase III. The time schedule and level of effort estimates for Phase III are difficult to define at this point and can be better defined at the completion of Phase II of the project.

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