Design and Construction of Falsework on Federal Lands Highway Projects

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FHWA has developed a research program to address bridge falsework design and construction. This program was initiated as a result of the findings from the investigation into the collapse of a bridge carrying the future eastbound lanes of Maryland Route 198 over the southbound lanes of the Baltimore-Washington Parkway on August 31, 1989. It was determined by the collapse review board that existing procedures for design and construction of bridge falsework were, at best, suspect. To guide and direct this program, FHWA formed the Scaffolding, Shoring, and Forming Task Group. Members of the task group represent state highway departments, contractors, manufacturers/suppliers, professional societies, TRB, and the federal government. Their task is to collect and develop a comprehensive design and construction specification relative to the use of temporary works for bridges.

On the morning of August 31, 1989, the final concrete placement for the top deck slab of a posttensioned concrete box girder bridge being constructed to carry the future eastbound lanes of Maryland Route 198 over the southbound lanes of the Baltimore-Washington Parkway was under way. Concrete placement for the top slab of the Maryland Route 198 bridge over the Baltimore-Washington Parkway started at about 2 a.m. so that the 154 yd^3 of concrete for the top deck could be placed and finished in the cool, early-morning temperatures. Suddenly and without warning, the supporting falsework collapsed. On the basis of concrete delivery tickets, 132 yd^3 of concrete had been placed at the time of the collapse. This left 16 to 20 ft of deck on the east end of the bridge remaining to be placed. The falsework consisted of three simple-span sections: a 35-ft roadway span and two 28-ft abutment spans. The superstructure construction was supported by timber formwork on steel longitudinal support beams that were supported by manufactured metal shoring towers, as shown in Figure 1. This scenario is becoming all too familiar in the bridge design and construction workplace of today. With an increase in the use of manufactured support systems, the design and construction of falsework are becoming more complex and critical parts of bridge construction.

The collapse of the falsework initiated a great deal of concern within FHWA and Congress as to the safety of current practices relative to falsework for bridges. The collapse occurred at about 6:50 a.m. during morning rush hour on the Parkway. Nine construction workers and five commuters were injured, with one sustaining serious injuries as a result of the collapse. There were no fatalities.

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FALSEWORK FAILURES

A number of other collapses have occurred since the Baltimore-Washington Parkway incident. On April 24, 1990, falsework for the Lake Street/Marshall Avenue bridge near St. Paul, Minn., collapsed, killing one worker. An estimated 300 tons of steel and 1,100 tons of concrete fell into the Mississippi River. According to the state bridge engineer, the failure was related to human design error.

On June 18, 1990, the falsework supporting one section of a 63-ft welded plate tub girder being erected at N-370 and US-75 in Bellevue, Nebr., collapsed, dropping the girder. There were no injuries. On the basis of investigation and analysis, the falsework collapse was initiated by lateral loads on the falsework caused by strong southwest winds. The failure of the falsework was progressive, ending with the collapse of the girder. The progressive failure sequence was simulated through transverse frame failure modeling. Wells Engineering, Inc., who investigated the cause of the collapse, ran an analysis of the falsework system. They found that some members could be expected to yield at wind speeds of 34 mph. Progressive collapse could be expected at certain joints at wind speeds of 37 mph. The Offutt Air Force Base Weather office verified winds in excess of 35 mph and gusting during the evening of June 18.

On July 13, 1990, the US-45 bridge under construction over Spring Brook in Antigo, Langrade County, Wisc., collapsed, as placement of deck concrete was nearing completion. The cause of the collapse is believed to be shear failure of the 48 bolts connecting the deck form supports to substructure abutment walls. This initial failure led to subsequent shear failure of all but one of the remaining bolts.

On October 10, 1990, at 1:18 a.m., a section of the superstructure falsework for an elevated connector ramp of the I-880/SR-238 interchange in San Leandro, Calif., collapsed. Three workers were injured, but there were no fatalities. The accident occurred during the erection of a falsework beam over an existing ramp. The cause of the collapse was determined by Caltrans to be related to erection errors.

RESEARCH PROGRAM

One of the recommendations made by the Collapse Review Board for the investigation into the Maryland Route 198 falsework collapse, and subsequently supported by Congress, was that FHWA should develop a research project on manufactured falsework assemblies. The study should be structured to improve present specifications and result in new guidelines

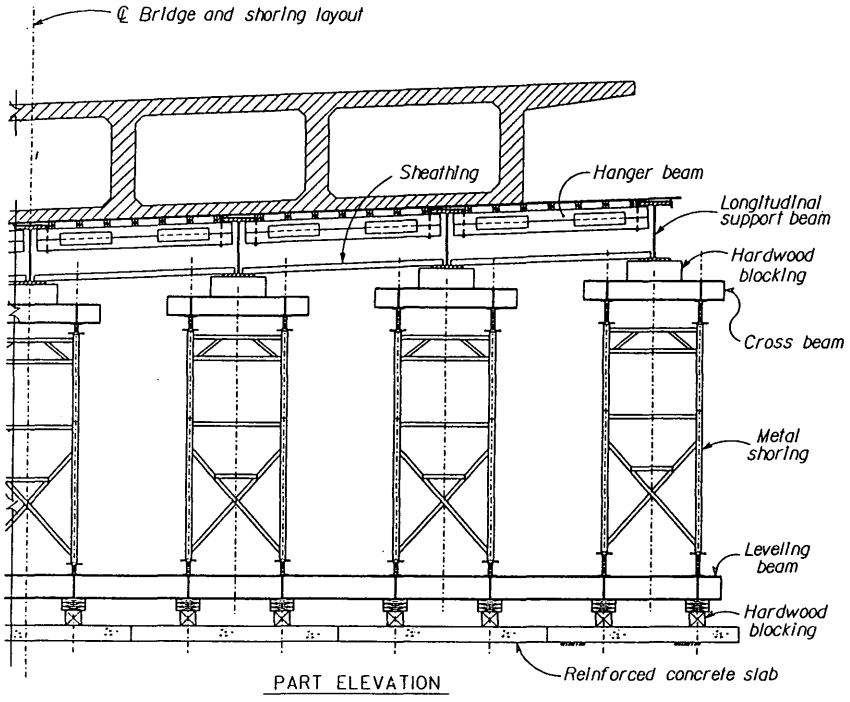

FIGURE 1 Superstructure construction for concrete girder bridge carrying Maryland Route 198 over Baltimore-Washington Parkway.

for design review and field inspection. There is also a pressing need for technical information on the various horizontal and vertical forces that interreact in shoring tower arrangements.

To implement this recommendation and to encourage cooperation, FHWA established the multidisciplinary Scaffolding, Shoring, and Forming Task Group to develop and guide the program. The Task Group includes representatives from FHWA; AASHTO; Associated General Contractors; American Road and Transportation Builders Association; TRB; the Scaffolding, Shoring, and Forming Institute; and ASCE.

The first task undertaken by the Task Group was to contract with a consulting firm to perform a synthesis of all existing codes and specifications dealing with bridge temporary works in the United States and abroad. This task was necessary because no national standards currently exist. In investigating the Maryland Route 198 collapse, it was felt that some industry practices relative to the safe use of metal shoring were not well documented and, consequently, not available to the engineers involved for consideration in reviewing the system used. Therefore, the Task Group felt that they needed to know the extent of temporary works design aids available in the worldwide engineering community before they could develop a concise manual addressing the design and construction of temporary works. The synthesis documents both the state of the art and the state of the practice. It also looked for any gaps or inconsistencies in existing specifications. After a vast amount of literature on temporary works was reviewed, it was found that on a worldwide basis, there are no major gaps in the understanding of temporary structures. However, the existing worldwide standards are not entirely adaptable to U.S. codes and construction practices and the proprietary shoring systems common to the U.S. construction industry. Despite the available information, the mistakes that contributed to prior falsework failures continue to be repeated. This suggests that although there may be no gaps in the understanding of temporary works, there is a problem with getting this information to the people doing the work.

Based on a review of current state practices, it is evident that design review and inspection procedures vary considerably from one state to another. This review covered all 50 states, the District of Columbia, Puerto Rico, and 12 Canadian provinces. As would be expected, states that are active in constructing cast-in-place concrete highway bridges are generally found to have comprehensive specifications and design guidelines, compared with those that mostly construct beam-type bridges. However, even in states that design and construct mainly beam-type bridges, a significant number of bridges are being built using cast-in-place construction methods that require extensive falsework. A clear need exists to develop unified design criteria and standards for temporary structures.

The second task undertaken by the Task Group was to develop a standard specification for bridge temporary works. The specification is written as a generic specification that can be used and modified by any state. It defines responsibilities of the parties involved at the time of bidding. Among other issues, it states that the contractor is responsible for designing and constructing safe and adequate temporary work systems. The selection of material suitable for falsework is the responsibility of the contractor, but subject to the engineer's review and approval. The contractor shall certify that the manufactured devices have been maintained in a condition to safely carry their rated loads. Each piece of manufactured shoring shall be clearly identified with regard to working load capacity. Working drawings shall be prepared by the con-

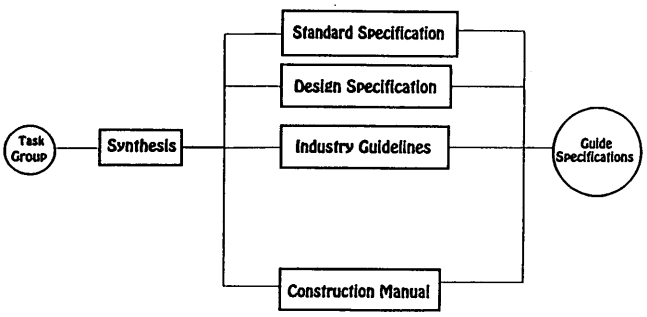

FIGURE 2 FHWA bridge temporary works research program.

tractor under the guidance of a registered professional engineer. Before placing concrete, the contractor shall have a professional engineer inspect the falsework and certify that the system is safe and erected in conformance with the approved working drawings.

The third task recognized by the Task Group was the need for a clear, practical design specification based on the best current technology (see Figure 2). A preliminary outline of the areas to be covered was developed by the group and given to a consultant for development. The design specifications will be modeled as much as practical around AASHTO's *Standard Specifications for Highway Bridges*. A comprehensive commentary will also be developed to record the origin and clarify the intent of the key provisions of the specifications. Temporary structures will include, as a minimum, scaffolding, shoring, forming, and cofferdams.

The fourth task to be undertaken was to ask the private-industry members of the Task Group to develop a set of criteria acceptable to the industry about instituting a certification program for individuals and companies involved with the design, handling, and erection of manufactured falsework assemblies.

The final task is to deal with the development of a construction manual. Realizing that some states do have good construction manuals, this task has been deferred until more work is done on the design specification development.

SUMMARY

The primary reason for this study was the collapse of the falsework on the Maryland Route 198 bridge over the Baltimore-Washington Parkway and subsequent recommendations by the Collapse Review Board to develop better specifications and guidelines. However, numerous other falsework collapses have occurred since then. Some have been design related, whereas others have been the result of poor construction practices.

The end product of the FHWA program is to develop a standard specification and a design manual on bridge temporary works with comprehensive commentaries, a synthesis of all codes and specifications dealing with the subject, and a construction manual if a need exists. These will be developed with input from representatives of AASHTO, private industry, and FHWA.

The guidelines and specifications developed will be applicable both to construction projects under the direct supervision of the Federal Lands Highway Office of FHWA and to projects carried out by the states with federal-aid highway funds. The end objective is to improve construction site safety.

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