National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: June 29, 2006

In reply refer to: H-06-23

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Assistant Secretary of Labor
U.S. Department of Labor
Occupational Safety and Health Administration
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The National Transportation Safety Board is an independent Federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendation in this letter. The Safety Board is vitally interested in this recommendation because it is designed to prevent accidents and save lives.

This recommendation addresses the inconsistency in regulatory requirements and guidance concerning falsework, bracing, and related temporary construction affecting highway construction contractors. The recommendation is derived from the Safety Board's investigation of the passenger vehicle collision with a fallen overhead bridge girder that occurred in Golden, Colorado, on May 15, 2004,[1] and is consistent with the evidence we found and the analysis we performed. As a result of this investigation, the Safety Board has issued five safety recommendations, one of which is addressed to the Occupational Safety and Health Administration (OSHA). Information supporting this recommendation is discussed below. The Safety Board would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendation.

On May 15, 2004, about 10:04 a.m., mountain daylight time,[2] a 2002 Dodge Durango sport utility vehicle (SUV) driven by a 34-year-old man eastbound on Interstate 70 (I–70) approached the Colorado State Route 470 (C–470) overpass.[3] The driver's 37-year-old wife and their 2-year-old child were also in the SUV. The interchange of I–70 and C–470 was in a temporary traffic control zone for a highway construction project, during which an additional entry ramp and two additional lanes were being constructed for the overpass.

[1] For additional information, read National Transportation Safety Board, *Passenger Vehicle Collision with a Fallen Overhead Bridge Girder, Golden, Colorado, May 15, 2004,* Highway Accident Brief NTSB/HAB-06/01 (Washington, DC: NTSB, 2006).

[2] Unless otherwise noted, all times in this letter are mountain daylight time.

[3] Structurally, an overpass is a bridge.

As the SUV approached the overpass, a fabricated steel girder line composed of two joined sections, which had been erected during the evening of May 11 through the early morning hours of May 12, 2004, parallel to the existing overpass, as a part of the bridge-widening project, rotated toward the overpass and sagged into the I–70 eastbound lanes. The girder struck the SUV about half the distance between the vehicle's front end and its windshield and sheared off the vehicle's top. The lower portion of the SUV continued east for 818 feet, coming to rest in the grassy median of I–70. All three vehicle occupants were killed.

The Safety Board determines that the probable cause of the May 15, 2004, girder collapse in Golden, Colorado, during a highway bridge-widening project was the failure of the girder's temporary bracing system due to insufficient planning by Ridge Erection Company, Inc., Asphalt Specialties, Inc., and the Colorado Department of Transportation, which were responsible for putting the girder and its bracing in place, and due to deficiencies in the installation of the girder and the bracing, so that the bracing ultimately failed to adequately secure the out-of-plumb girder to the existing bridge deck. Contributing to the accident was the lack of uniform, consistent bracing standards and the Colorado Department of Transportation's narrow definition of falsework, which did not include lateral bracing. Also contributing to the accident was the failure of the Colorado Department of Transportation to effectively oversee safety-critical contract work for the project.

To understand this accident, a description of the events preceding it is necessary. The Federal Highway Administration (FHWA) and the State of Colorado funded the I–70/C–470 interchange construction project, which was intended to improve traffic capacity and safety at the interchange of these two routes and to make additional improvements along I–70 in this area. As a part of the project, the overpass of I–70 by C–470 was to be widened by adding two lanes. An additional loop ramp was also to be constructed. Under the terms of the stewardship agreement between the FHWA and the Colorado Department of Transportation (CDOT), CDOT was managing the project[4] and had contracted with Asphalt Specialties, Inc., to perform the actual construction work. Asphalt Specialties had been the general contractor for numerous projects in Colorado for CDOT and other agencies.

CDOT prequalified Asphalt Specialties as the prime contractor[5] for this project. The prequalification process is governed by the Colorado rules of prequalification and can be found in the *Rules for Prequalification, Debarment, Bidding, and Work on Colorado Department of Highways' Road, Highway, and Bridge Public Projects*.[6] In these rules, prequalification is defined as follows:

[4] The purpose of the stewardship document was to set forth an agreement between CDOT and the FHWA Colorado Division Office regarding their respective roles and responsibilities in administering the Federal-aid highway program in Colorado. This stewardship agreement outlined the project approval authorities that CDOT and the FHWA agreed upon in accordance with 23 *United States Code* 106. Under the agreement, CDOT project-level oversight included its taking over FHWA responsibilities for all reviews and approvals associated with the design and construction, including final inspection, of Federal-aid projects.

[5] CDOT refers to the contractor responsible for engaging and monitoring subcontractors as the "prime" contractor.

[6] Additional information may be accessed at <http://www.dot.state.co.us/Bidding/index.htm>.

> The process of review by CDOT of a contractor's fiscal and workmanship qualifications to perform work on public projects through which CDOT determines whether the contractor will be permitted to submit bids as provided in these rules. (See 2 *Code of Colorado Regulations* 601-10, Section 1.03(ff).)

These Colorado rules require the potential prime contractor to file a prequalification application and questionnaire with the CDOT staff construction engineer or designee. To complete the prequalification application, the prime contractor must (among other requirements) indicate its previous experience in highway construction work, detail the number of years' experience in various types of highway work, and list all construction contracts, both highway and nonhighway, performed in the past 3 years.

One of the purposes of prequalification is to ensure that the contractor is technically proficient in performing highway construction. Proficiency entails the contractor having had recent relevant experience and being familiar with standard highway construction regulations, specifications, and guidelines, such as those issued by the FHWA, CDOT, and the American Association of State Highway and Transportation Officials (AASHTO).[7]

Asphalt Specialties subcontracted with steel erection firm Ridge Erection Company, Inc., (Ridge) to erect the three new girders needed to widen the C–470 bridge. The FHWA and CDOT permit up to 70 percent of a project's work to be done by subcontractors, pursuant to 23 *Code of Federal Regulations* (CFR) 635.116. According to the Colorado prequalification rules, CDOT is not required to prequalify subcontractors on its projects,[8] and CDOT did not prequalify Ridge. CDOT records show that between 1987 and 1990, Ridge erected bridge girders on nine CDOT projects. According to Ridge records, in the 14 years preceding the accident, Ridge had not worked on any highway bridge projects.

For the bridge-widening project, three complete girders, each composed of three separate sections, were to be installed to the east of the existing C–470 bridge deck. Initially, only the first two sections were to be set for each of the first two girders. The third sections, completing these girders, were to be installed and spliced to these two-section girder lines at a later date. Each two-section girder line was to be cantilevered over the center pier for the bridge expansion.

The girder installation work that ultimately led to this accident was the subject of a March 24, 2004, planning meeting, which was attended by representatives from CDOT, Asphalt Specialties, and Ridge.[9] According to Ridge representatives,[10] at this meeting, Ridge officials said they planned to set 2 two-section girder lines to the east side of the C–470 bridge during the

[7] AASHTO is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 States, the District of Columbia, and Puerto Rico. AASHTO documents are used as reference and guidance materials by State highway and transportation departments.

[8] Safety Board staff contacted 15 randomly selected State departments of transportation or highways to determine how other States address the qualifications and competence of subcontractors. Of the 15 States contacted, 5 required prequalification of subcontractors.

[9] No written documentation was made of the meeting. All information is based on Safety Board investigators' postaccident interviews with meeting participants.

[10] Including Ridge's vice president.

evening of May 11 through the early morning hours of May 12, 2004. (The two-section girder lines will henceforth be referred to as "girders.")

According to Ridge, to install the two girders, workers were to use cranes to pick up the first girder's two sections, splice them together while they were held in the air by the cranes, and then set the first girder in place parallel to the C–470 bridge deck. Next, while being held by the cranes, the first girder was to be braced to the existing C–470 bridge deck with angle-shaped steel braces ("angle irons") bolted to the new girder and attached to the paved bridge deck with expansion bolts. Once it was temporarily braced in this manner, the first girder would be released from the cranes. Then, the second girder would be installed the same way, and, once it was in place, the two girders would be cross-braced with diaphragms[11] to stabilize them. Ridge said that if only the first girder could be erected that night, it intended to stabilize the single girder by connecting it to the existing C–470 bridge deck with the angle braces, in the manner described above for the temporary bracing to keep one girder in place, and erection of the second girder would continue the following night.

Ridge officials stated that the Ridge safety officer developed the bracing plan for a single girder and made a non-scale, hand-drawn sketch of it. The Ridge safety officer had been a Ridge employee for more than 20 years, initially as an ironworker (holding positions that included foreman, general foreman, and superintendent), and eventually was named safety officer in 1998. He had no training or certification in engineering. No copy of his bracing plan sketch could be provided to the Safety Board after the accident.

Attendees recalled little discussion of the temporary bracing at the March 24 meeting.[12] The Ridge safety officer characterized the talk concerning the temporary bracing as a brief discussion of 3 to 5 minutes' duration. The CDOT project engineer stated that he did not recall any specific discussion of the bracing, but he thought it might have been mentioned "in passing." The CDOT inspector said he did not recall any discussion of the temporary bracing but could not say that it was not discussed. Asphalt Specialties' general superintendent and traffic control supervisor said that few details were discussed with respect to the bracing plan. They recalled no drawings of any kind being presented. The Asphalt Specialties concrete structural superintendent recalled that angle braces were mentioned with respect to the temporary bracing. He had no recollection of any discussion concerning "X" bracing (cross bracing between two girders) or a plan to secure a single girder to the existing bridge structure. The Asphalt Specialties project manager stated that the temporary bracing was briefly discussed, and he recalled that CDOT officials told Ridge representatives that they could not weld to the existing structure. He said that a few ideas were discussed, but nothing was decided about how the bracing was to be accomplished.

[11] A *diaphragm* in this usage is a system of cross braces between two or more parallel girders.

[12] After the accident, Ridge officials told Safety Board investigators that, in preparation for the erection, it had proposed three bracing methods, including using permanent diaphragms between the new girder and the existing C–470 bridge. Ridge stated that it also suggested using temporary cross braces bolted or welded to the existing bridge. Ridge stated that it was told that the diaphragms had not been designed and fabricated yet and that it could not attach cross braces to the existing bridge web with bolting or welding, even if they were temporary and later removed. Consequently, Ridge stated that it had to use its third alternative, bolting angle braces to the top deck of the C–470 bridge roadbed.

The contract for the C–470 bridge-widening project did not require that the contractor or subcontractor submit plans for the erection of the girders or the girder bracing. CDOT did not request, and neither the contractor nor the subcontractor prepared, a formal design or plan for the erection of the girders or the girder bracing.

No Registered Professional Engineer[13] reviewed or was otherwise directly involved in Ridge's plans. A Registered Professional Engineer must be registered as a qualified engineer in the State. According to the Colorado State statute for registration of engineers,

> In order to safeguard life, health, and property and to promote the public welfare, the practice of engineering is declared to be subject to regulation in the public interest. It shall be deemed that the right to engage in the practice of engineering is a privilege granted by the state through the state board of licensure for professional engineers and professional land surveyors, created in section 12-25-106; that the profession involves personal skill and presupposes a period of intensive preparation, internship, due examination, and admission; and that a professional engineer's license is solely such professional engineer's own and is nontransferable. (12-25-101.)

On May 5, 2004, Ridge and Asphalt Specialties held a meeting at the construction site to discuss the placement of cranes. On May 10, they held a meeting to make a final check of the crane pads and cranes. According to CDOT, it was never notified of these meetings, and no one from CDOT attended either meeting.

The task of erecting the two girders over I–70 parallel to the C–470 bridge deck was scheduled to take place from 9:00 p.m. on Tuesday, May 11, until 5:00 a.m. on Wednesday, May 12. During this 8-hour period, I–70 was to be closed to allow the girder erection equipment (including cranes) access to the east- and westbound lanes and median of I–70. This roadway had average traffic of about 76,000 vehicles per day. During the work period, traffic was to be routed onto a series of frontage and paralleling routes west of the work site. The Colorado State Patrol had a patrol car positioned near the I–70 closure area to slow traffic.

Work began about 9:00 p.m.,[14] as scheduled. Present at the work site were CDOT's project engineer, two inspectors, and a senior executive service engineer (this individual left about 12:30 a.m. and did not return that night). Four Asphalt Specialties supervisors and three workers were on scene, as were two Ridge supervisors and eight workers.

Between about 9:00 p.m. and 11:00 p.m., Ridge workers positioned the cranes and moved the girder sections into place for lifting with the cranes. The weight of one girder section was approximately 20,000 pounds or 10 tons, and two girder sections spliced together weighed approximately 40,000 pounds or 20 tons. With two sections spliced together, each girder was approximately 204 feet long. The distance from the south abutment to the center bridge pier for

[13] The terms "Professional Engineer," "Registered Engineer," and "Registered Professional Engineer" are used interchangeably in the construction industry.

[14] All times indicated as referring to tasks and events that took place the night of the girder erection are rough estimates, based on the sometimes conflicting recollections of witnesses, all of whom were recalling incidents that had taken place at least several days earlier. The sequence of events is generally not in dispute, but the times at which they took place sometimes differed from one witness's account to another's.

the expansion was approximately 154 feet, and a two-section girder would be cantilevered over the center bridge pier and extend beyond the pier by about 50 feet.

Between about 11:00 p.m. and 12:30 a.m., Ridge employees began raising the girder sections, and they encountered problems. Ridge did not have impact wrenches or similar tools to facilitate removal of the numerous shipping bolts[15] on the girder sections. Consequently, workers had to use hand tools to remove these bolts. A cutting torch was needed to remove some of the shipping bolts.

According to the CDOT lead inspector, after Ridge workers had lifted the two sections of the first girder with cranes and were attempting to splice them while the sections were suspended in air, he noticed that one of the two sections was backward. According to Ridge, the fabricator's drawing indicated that a piece mark was located on what was to be the north end of the girder section for the project. The permanent piece mark was stamped into the steel section, consistent with the fabricator's drawing; however, the fabricator had painted over[16] this stamped piece mark. When the Ridge workers checked the section, they found hand-applied alphanumeric characters, which are used to identify the section, on the end opposite from the piece mark. They mistakenly used these alphanumeric characters to position the section, and as a result, raised it backward.

The CDOT lead inspector informed the workers of the mistake, which meant that the backward girder section had to be rotated 180 degrees before the two sections could be spliced. He said he had some difficulty persuading the Ridge workers that the section was backward, but they ultimately agreed and reversed the section. Sometime between midnight and 1:30 a.m. (witness accounts concerning the time vary considerably), the mid-air splicing process resumed. The CDOT lead inspector estimated that the splicing would take until about 4:00 a.m. to complete.

Those on the C–470 bridge work site realized that they would not have time to erect the second girder before I–70 was scheduled to reopen at 5:00 a.m.[17] Consequently, the Ridge crew had to postpone this task and intended to perform it on the next night.

During the approximately 4 hours that the girder sections were being bolted together, the CDOT lead inspector and project engineer left the C–470 bridge site and drove to another work site for this project to look at repairs being performed by another work crew. They also stopped by an area of the traffic detour where, between about 11:00 p.m. and 1:00 a.m., an eastbound tractor-semitrailer truck driver had mistakenly driven down an exit ramp from I–70 and then eastbound in the westbound lanes, where workers were in the roadway. (No accident resulted from the truck's incursion into the work zone.) According to the CDOT lead inspector, they returned to the C–470 bridge site about 4:00 a.m.

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[15] Shipping bolts are used to attach the splice plates to the girder for shipment from the shop to the construction site. The shipping bolts had to be removed before the bolts needed to join the two sections could be inserted.

[16] It is standard industry practice to paint girders.

[17] After the accident, CDOT and Asphalt Specialties personnel questioned whether it would have been feasible, even had time not been lost due to removing the shipping bolts with hand tools and repositioning the backward girder section, to have installed two girders in one night.

About 3:45 a.m. to 4:00 a.m., Ridge workers began installing bracing to temporarily stabilize the single girder. They intended to install five angle-shaped steel braces to connect the single girder with the edge of the deck on the existing C–470 bridge. The braces were fabricated on site. To bend the braces, workers used a cutting torch to cut one leg of each brace (except the third brace, which was not cut). They also used torches to cut circular holes in the braces for the expansion bolts that would connect them to the bridge deck. Postaccident examination showed that these cutting procedures reduced the cross section of the braces by about half.

Bolts were to be used to connect the girder to the braces, and expansion bolts were to be used to connect the braces to the bridge deck. When Ridge's workers bored holes in the bridge deck and attempted to install expansion bolts in them, they found that the bolts they had on hand were too long for the bridge deck holes.[18]

The existing C–470 bridge deck was composed of Portland cement concrete. As originally designed and constructed, the bridge deck had an asphalt overlay that measured from 1.7 to 3 inches thick at the expansion bolt locations. The Portland cement concrete bridge deck was in good condition. Its thickness was about 8.25 inches. The asphalt overlay was generally in poor condition at the edge of the bridge deck, near where the expansion bolts for the bracing were to be inserted. The overlay had deteriorated and had been damaged by prior construction activity to remove the existing bridge rail at the edge of the bridge deck, in preparation for the bridge widening.

After workers made several unsuccessful attempts to make the bolts connecting the braces to the deck work, an employee was dispatched to the Ridge shop[19] about 4:30 a.m. to acquire different expansion bolts. These new bolts were put in, completing the girder bracing, and I–70 was reopened a half hour later than planned, about 5:30 a.m.

In a postaccident interview, the CDOT project manager stated that he believed no one on the construction site thought the accident girder was unsafe when the crew left it. He said, "If there was a known safety problem, the road could have been closed longer." He also said they could have kept the cranes attached to the girder if it had been considered unsafe.

Aside from the CDOT lead inspector who pointed out that Ridge was attempting to splice two sections of girder with one section backward, the CDOT construction supervisors did not question the adequacy of the subcontractor's work on the C–470 bridge project during the night. No one from CDOT or Asphalt Specialties objected to the lack of a written bracing plan or to the means used to install the bracing.

The work crew intended to install the second girder on the following night. No one on scene in the early morning hours of May 12 checked the weather forecast to determine whether conditions would be favorable for such work that night. As of 4:11 a.m., May 12, the National Weather Service forecast for the area called for temperatures in the mid-30s° F, winds of 15 to 20 mph, and likely precipitation for the evening of May 12. This forecast indicated that expected weather conditions were not favorable for installation of the second girder that night. The

[18] The CDOT lead inspector stated that he watched Ridge's bolting activities from a position on I–70 and that he could "hear and see the drilling and hammering" of the bolts.

[19] The Ridge shop was about 10 miles away.

extended weather forecast showed that precipitation and low temperatures in the 30s° F were expected for several nights to come. Winds of 15 to 20 mph were predicted for May 14. Ultimately, Asphalt Specialties and Ridge postponed the completion of the girder installation for more than 3 days.[20]

After work was concluded on the morning of May 12, an Asphalt Specialties project supervisor did check the weather forecast and became concerned about the possible effects of the wind on the temporarily braced single girder. He said he returned to the site about 8:45 p.m. on May 12 and inspected the girder and its bracing.[21] He found nothing wrong with the installation. (He later said that he may not have noticed a small angle of deflection of the girder.) No one involved with the project periodically inspected the girder or its bracing following the May 12 installation.

On May 13, a traveler driving westbound on I–70 incidentally made a digital image of the accident girder through the car's windshield. After the accident, Safety Board investigators examined this image and found that it indicated that at this time the accident girder appeared to be leaning toward the existing bridge deck by about 5 degrees between the south abutment and the center bridge pier for the extension and by about 1 degree beyond the center bridge pier.

On May 14, two travelers westbound on I–70 separately noticed anomalies involving the girder but did not report them. The first, who passed under the C–470 overpass about 1:30 p.m., later stated that the girder appeared to have been "tilted." The second traveler, who made the observation about 8:30 p.m., indicated postaccident that the girder had been "leaning" toward the bridge.

On the morning of May 15, two I–70 travelers, one about 8:00 a.m. and the other about 8:30 a.m., noticed irregularities in the girder's position. Neither reported the observations until after the accident. The first traveler noted that the girder was leaning toward the bridge. The second saw a "wave" in the girder.

At 8:49 a.m. on May 15 (about 75 minutes before the accident), a traveler on I–70 called 911 to report that the girder was "twisted." The caller reached the Jefferson County Sheriff's Office, which transferred the call to the Colorado State Patrol dispatcher. The dispatcher evidently misunderstood a term the caller used in his statement and, when repeating the message to the caller, indicated that a sign was involved. The caller confirmed the dispatcher's restatement of the message, including the erroneous information that a sign was involved. The report was misinterpreted to involve a "damaged sign" on I–70; this was the message CDOT received about 9:00 a.m. CDOT dispatched two highway maintenance workers (each in a separate truck) in response. They located a leaning sign on the C–470 overpass (adjacent to the new construction) and assessed its condition. They then notified the Colorado State Patrol that the problem sign had been found, that it was not interfering with traffic, and that it would be fixed in the next few days. They returned to the CDOT equipment shed and had been there for about 15 minutes when they were told that the accident had occurred.

[20] Until the accident occurred on the morning of May 15.

[21] U.S. Naval Observatory data show that the end of "civil twilight" occurred at 8:36 p.m. on May 12, 2004. Civil twilight refers to the period during which twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished.

About 9:00 a.m., a CDOT bridge engineer (not involved with this project) was exiting northbound C–470 onto eastbound I–70. While traveling roughly parallel to the accident girder, this CDOT employee observed that the girder was "buckled toward the existing bridge," but she did not notify anyone. She later said that she did not know whether the girder's condition was abnormal. At the time of the accident, CDOT had an emergency call list in place for use by its staff, and CDOT periodically updated this list. However, the bridge engineer said she did not know whom she should call.

Accident reconstruction[22] indicated that the Dodge Durango SUV was traveling approximately the posted speed limit of 65 mph as it approached the C–470 overpass about 10:04 a.m. About that time, the temporarily braced and unstable girder rotated toward the overpass and sagged into the path of the oncoming vehicle. The girder struck the SUV, killing the victims instantly.

After the accident, investigators examined and measured the fallen girder, the braces, the south abutment, the C–470 bridge, and the center bridge pier for the extension. Evidence indicated that the girder had been installed 4.26 degrees out of plumb at the south abutment and 2.33 degrees out of plumb at the center bridge pier, leaning toward the existing bridge. The five lateral braces, which were fabricated on site, had been intended to connect to a correctly installed (fully plumb) girder and to be bolted flush with the existing bridge deck. None of the braces were flush with the deck.

The bracing's failure occurred at the bridge deck, when the lateral force from the girder's distortion placed loads on the expansion-bolted connections, separating the expansion bolts from the bridge. Postaccident examination indicated that the expansion bolts used to connect the braces to the bridge deck were, in various ways, not installed in accordance with manufacturers' requirements. In particular, the Safety Board Materials Laboratory found that the bolt hole diameters in the existing bridge deck measured 0.90 inch while the diameters of the expansion bolts were only 0.75 inch. A 0.75-inch-diameter expansion bolt set in a 0.90-inch-diameter hole required the presence of a horizontal load to maintain some pullout resistance. The horizontal loads at the time of the girder erection levered (or cocked) the bolts in the holes. Once the horizontal load decreased in magnitude or changed direction, the pullout resistance was immediately lost. Over time, the varying cyclical loads on the bolts caused by lateral vibrations, thermal expansion and contraction loads, and wind loads would have resulted in variations to the horizontal loads on the bolts, which eventually would have led to the bolts pulling out of the holes.

In addition, all but one of the expansion bolts were not embedded in the concrete according to manufacturers' installation requirements. These requirements were that the bolts must be embedded to a minimum depth of 3.25 inches. Investigators determined that, with the exception of one bolt,[23] the expansion bolts were embedded in concrete to depths of from 1.25 to 2.50 inches.

[22] Reconstruction efforts involved investigators from law enforcement agencies, the FHWA, the Safety Board, and CDOT.

[23] This bolt was embedded to a depth of 4.75 inches.

After the accident, the FHWA Turner-Fairbank Highway Research Center conducted a finite element analysis of the girder collapse to identify likely scenarios and to assist in determining the likely or possible sequence of events between erection and collapse of the girder. The FHWA developed a finite element analysis model to simulate the response of the braced girder under 10 load scenarios; various combinations of braces were removed, and additional wind loading was applied. The addition of wind loading had minimal effect on the deflected shape of the girder. The second (from the south) of the five braces appeared to be the most critical to providing stability for the girder. Removal of this brace caused immediate instability for the out-of-plumb girder. The analysis found that cyclic forces on the braces due to lateral vibrations and wind loads from May 12 through 15, 2004, were primary factors in weakening the incorrectly installed expansion bolts over time.

Thus, Ridge's erection of the girder and installation of the temporary bracing were inadequate. Had the girder been installed in plumb or had the bracing been bolted effectively, the bracing might not have failed and the girder might not have lost stability, causing it to rotate toward the overpass and sag onto I–70 on the morning of May 15. But in combination, the out-of-plumb girder and improperly installed bolts resulted in an insecure bracing arrangement that was not adequate in the short or long term.

Moreover, the planning for the bracing lacked forethought and precaution. According to Ridge, its original intention was that this bracing arrangement was to be used to secure the single girder for a relatively brief period during the 8 hours of work beginning on the evening of May 11 while a second girder was set in place. Thereafter, the permanent cross bracing with diaphragms would have secured the two girders to each other. But planning for the bracing apparently did not take into consideration the possibility that only one girder might be installed and that the bracing might need to secure a girder for longer than a few hours. Because no contingency plan had been developed for securing a single girder, Ridge used this temporary bracing system, originally intended to stabilize the girder for a few hours, for more than 3 days, during which it was vulnerable to stresses caused by temperature variations, winds,[24] and vibrations from passing traffic.

One issue that the Safety Board identified during this investigation was the inconsistency in regulatory requirements and guidance concerning falsework,[25] bracing, and related temporary construction affecting highway construction contractors. The safety and adequacy of such temporary construction are important considerations during the erection of steel structures.

In 29 CFR Part 1926, "Safety Standards for Steel Erection," OSHA has regulations relating specifically to the erection of steel structures. After the accident, the Ridge vice president told Safety Board investigators that he believed he should follow the OSHA steel girder erection regulations and that he considered Ridge had fulfilled the OSHA requirements on the C–470 bridge project. CDOT told Safety Board investigators that it was unaware of the OSHA rules relating to the erection process. Safety Board communication with AASHTO and

[24] Winds had been relatively strong during the night preceding the accident, and temperatures had begun to rise gradually during the day of May 14. Both these factors may have stressed the girder's bracing.

[25] In the construction industry, *falsework* is generally considered to be a structure or frame that supports something temporarily, while it is being built.

the American Society of Civil Engineers indicated that they, too, were unaware of the OSHA rules.

The summary information at 29 CFR Part 1926, "Safety Standards for Steel Erection; Final Rule," dated January 18, 2001, states the following:

> By this notice the Occupational Safety and Health Administration (OSHA) revises the construction industry safety standards which regulate steel erection. The final rule enhances protections provided to workers engaged in steel erection and updates the general provisions that address steel erection. The final rule sets performance-oriented criteria, where possible, to protect employees from steel erection related hazards such as working under loads; hoisting, landing and placing decking; column stability; double connections; hoisting, landing and placing steel joists; and falls to lower levels. To effectuate this, the final rule contains requirements for hoisting and rigging, structural steel assembly, beam and column connections, joist erection, systems engineered metal building erection, fall protection and training.

This statement suggests that OSHA's steel erection regulations are safety standards primarily concerned with protecting workers. The OSHA regulations apparently are not designed to serve as engineering standards or instructions but to provide protective measures for construction workers.

Title 29 CFR 1926.752, "Site layout, site-specific erection plan and construction sequence," states that OSHA requires that the contractor adhere to the following requirements (in addition to others) before construction may begin:

> (d) Pre-planning of overhead hoisting operations. All hoisting operations in steel erection shall be pre-planned to ensure that the requirements of § 1926.753(d) are met.
>
> (e) Site-specific erection plan. Where employers elect, due to conditions specific to the site, to develop alternate means and methods that provide employee protection in accordance with § 1926.753(c)(5), § 1926.757(a)(4) or § 1926.757(e)(4), a site-specific erection plan shall be developed by a qualified person and be available at the work site.

OSHA defines a "qualified person," as indicated in section (e) above, as

> One who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter, the work, or the project.

Nothing in the definition requires that this person be a Registered Professional Engineer, an individual whose engineering competence has been approved and certified by the State. In the case of this accident, Ridge considered its safety officer to be a "qualified person" in accordance with OSHA regulations. The safety officer had no engineering credentials, and Ridge had not worked on a highway bridge project for 14 years.

At 29 CFR 1926.754(a), "Structural steel assembly," OSHA further requires that "Structural stability shall be maintained at all times during the erection process."

OSHA was a party to this investigation and was asked to review its regulations and determine their applicability to the steel erection activity involved in this accident. The Denver OSHA office furnished the following evaluation of "potential" [26] violations of OSHA regulations that may have existed during the attempted erection of the accident girder:

- Failure to maintain stability of the girder at all times during erection of the steel structure. (See OSHA 1926.754(a).)
- Lack of an erection plan by the steel erector that provided a method and means for bracing the girder.
- Improper proportioning of the lateral braces and their anchorage by the steel erector. (Braces are engineered, whether temporary or permanent, with due regard to the cross section and end conditions of the girder, in accordance with the design standards of the industry.)
- A reduction in the cross sectional area of the braces by 50 percent or more by arbitrarily flame-cutting one of the legs to facilitate field bending the braces, without any engineering evaluation.
- Improper installation of the braces by the steel erector, without engineering evaluation, before the girder had undergone dead load deflection. (Note that the girder was still being held by at least one crane while the braces were installed.)
- Lack of professional diligence on the part of the Colorado Department of Transportation's site representative, who had control and authority over the construction site. The site representative reportedly permitted the contractor to proceed with the erection of the girder without any erection plan and without ensuring the lateral stability of the girder.
- Failure on the part of the steel erector to ensure the plumbness of the girder after the braces were installed and anchored to the concrete deck. Note that the girder was braced while at least one crane was still reportedly holding the load. Transits were not reportedly used at the site.

Thus, according to OSHA's informal evaluation, Ridge may not have fulfilled its OSHA regulatory requirements in carrying out the installation and bracing of the accident girder.

OSHA regulations were not the only directives the contractor and subcontractor could have used in erecting the C–470 bridge structures. CDOT, AASHTO, and the FHWA (among others) have all issued guidance on this subject. Worth noting is that the OSHA steel erection regulations do not cover some significant elements of such work. For example, the OSHA

[26] OSHA did not conduct an official evaluation of this work site and took no official action concerning it. This informal evaluation, conducted postaccident at the Safety Board's request, indicates areas in which the Denver OSHA office believes that OSHA regulations may not have been fulfilled.

regulations do not specifically define or discuss falsework, yet the definition of falsework as it applied to the Golden highway construction project was crucial to those carrying it out. In Section 601, "Structural Concrete,"[27] at Subsection 601.11, "Falsework," the CDOT *Standard Specifications for Road and Bridge Construction*, define falsework as "any temporary construction used to support vertical loads for a structure until it becomes self-supporting."[28]

After the accident, CDOT and the FHWA Colorado Division Office told Safety Board investigators that, in light of this definition, they considered the temporary lateral braces that supported the girder to be "braces" rather than "falsework" because they did not support vertical loads. Both Ridge and Asphalt Specialties also referred to the structure as "bracing." Because the contractor and subcontractor considered the structure bracing rather than falsework, they thought that this work did not need to follow the specific guidance for falsework provided in the CDOT specifications. Nor did CDOT require the contractor or subcontractor to follow such guidance. Given this situation, and the fact that no OSHA regulations specifically address falsework, Ridge was not bound to fulfill any specific requirements concerning such temporary construction. In this case, failure to follow well-considered, prudent practices concerning falsework that consistent guidance and regulation could have provided led to improper temporary bracing of the accident girder. As a result, the bracing failed, allowing the girder to fall and to cause a fatal accident.

Subsection 601.11 of the CDOT specifications[29] recommends the following for designing and constructing falsework:

> The Contractor shall be responsible for designing and constructing falsework which provides the necessary rigidity, supports the loads imposed, and produces in the finished structure the lines and grades indicated on the plans.
>
> The Contractor shall have a Professional Engineer determine whether falsework drawings are or are not necessary. When falsework drawings are determined to be unnecessary, the Contractor shall submit a written statement signed by the Contractor's Professional Engineer so stating.

On this project, neither the contractor nor the subcontractor had a Registered Professional Engineer determine whether falsework drawings were necessary for the C–470 bridge-widening project; they also did not submit a written statement to CDOT, signed by a Registered Professional Engineer, indicating that falsework drawings were unnecessary. Such drawings, if they had been properly prepared by a qualified engineer, might have included information concerning the need for a plumb girder, the condition of the existing bridge pavement, and the

[27] The guidance concerning the erection of steel structures in the CDOT *Standard Specifications for Road and Bridge Construction* and the *CDOT Construction Manual* recommends that falsework for steel structures conform to the guidance in the structural concrete section of the CDOT specifications. See Colorado Department of Transportation, *Standard Specifications for Road and Bridge Construction* (Denver, CO: CDOT, 1999), Section 509, "Field Construction Requirements," Subsection 509.27, "Erection of Steel Structures," 461; and Colorado Department of Transportation, *CDOT Construction Manual* (Denver, CO: CDOT, 2002), Section 509, "Steel Structures," Subsection 509.2.2 (2) "During Construction—Falsework Considerations," 500–29.

[28] CDOT *Standard Specifications for Road and Bridge Construction*, 550.

[29] CDOT *Standard Specifications for Road and Bridge Construction*, 550–551.

specific equipment needed to install expansion bolts successfully, given the pavement condition. Had the temporary bracing been considered falsework, and had it been constructed in accordance with the requirements in the CDOT specifications concerning falsework, the bracing might have been adequately planned and installed, and the accident might not have occurred. Had OSHA provided similar regulations concerning falsework installation, such reasonable precautions would have been required by Federal law.

The AASHTO *Standard Specifications for Highway Bridges*, Section 3, "Temporary Works," 3.2 "Falsework and Forms," 3.2.1 "General,"[30] define falsework as follows:

> Falsework is considered to be any temporary structure which supports structural elements of concrete, steel, masonry, or other materials during their construction or erection.

Thus, it appears that, under the fairly broad AASHTO definition, the bracing installed in the early morning hours of May 12, 2004, would have been considered falsework. With respect to falsework over publicly traveled ways, the AASHTO *Standard Specifications for Highway Bridges*[31] recommend the following:

> Whenever the height of falsework exceeds 14 feet or whenever traffic, other than workmen involved in constructing the bridge, will travel under the bridge, the working drawings for the falsework shall be prepared and sealed by a Registered Engineer.

In this instance, traffic did pass under the bridge, but again, because of discrepancies in the definition of the term "falsework" in the CDOT and AASHTO guidance documents and the absence of specific regulations from OSHA in this area, no Registered Professional Engineer was involved in this aspect of the project. The Ridge safety officer, who had no engineering training or certification, reportedly prepared a hand-drawn sketch of the bracing plan to connect the girder to the existing bridge deck. Had this task been undertaken by a Registered Professional Engineer, the bracing drawings might have contained information concerning important factors such as ensuring that the girder was plumb, checking the pavement condition, and providing the tools and processes needed to install expansion bolts adequately, which might have helped workers install the bracing properly so that it would not fail.

In addition, with respect to planning the construction and removal of falsework, the FHWA *Guide Design Specification for Bridge Temporary Works* recommends the following for falsework over publicly traveled ways:[32]

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[30] American Association of State Highway and Transportation Officials, *Standard Specifications for Highway Bridges*, 17th ed. (AASHTO, 2002) 484.

[31] AASHTO *Standard Specifications for Highway Bridges*, 484.

[32] Federal Highway Administration, *Guide Design Specification for Bridge Temporary Works*, FHWA-RD-93-032 (Washington, DC: FHWA, November 1993) 3.

> Where temporary bracing is to be used during erection and removal of falsework over or adjacent to public traffic, the falsework drawings shall show the sequence of erection and removal and details of the temporary bracing system to be used.

Ridge does not appear to have prepared any formal falsework drawings showing the sequence of erection and removal or other information pertaining to the temporary bracing system to be used. Had such drawings been prepared, the information in them might have helped workers install the bracing system more effectively (such as by ensuring that the girder was plumb, using appropriate bolting methods, and allowing for the poor deck overlay condition), which might have prevented the accident. However, Ridge was unlikely to have prepared falsework drawings in the absence of an OSHA requirement to do so and given the lack of consistent guidance concerning falsework among CDOT, the FHWA, and AASHTO.

The evidence from the Golden accident indicates that the lack of consistent terminology and direction concerning falsework, bracing, and related temporary construction activities in OSHA's steel erection regulations and in CDOT, AASHTO, and FHWA guidance documents may have led to insufficient use of technical expertise in preparing for and installing the temporary bracing intended to hold the accident girder in place. In particular, the fact that OSHA's regulations do not specifically address structures constructed to provide temporary stabilization of ongoing work (falsework) is a matter for concern. If other steel erectors share Ridge's belief that regulatory responsibilities when undertaking steel erection activity are limited to those specified in the OSHA regulations, many steel erection contractors may not be following appropriate guidance when constructing falsework. The OSHA regulations, which have the weight of law affecting steel erection construction throughout the Nation, should be no less rigorous in this important safety area than the guidance documents provided by the FHWA and AASHTO. To ensure consistent, adequate guidance and requirements concerning the erection of steel falsework, discrepancies among these three organizations' guidance and regulatory documents, which are used by the construction industry nationwide, should be eliminated.

Therefore, the National Transportation Safety Board recommends that the Occupational Safety and Health Administration:

> Work with the Federal Highway Administration and the American Association of State Highway and Transportation Officials to make consistent and compatible your organizations' regulatory requirements for and guidance to construction contractors concerning the design and certification of falsework, formwork, and bracing for the erection of highway structures, including the regulations and guidance concerning the need to have the designs prepared or approved by a Registered Professional Engineer. (H-06-23)

The Safety Board also issued safety recommendations to the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the Colorado Department of Transportation.

In your response to the recommendation in this letter, please refer to Safety Recommendation H-06-23. If you need additional information, you may call (202) 314-6177.

Acting Chairman ROSENKER and Members ENGLEMAN CONNERS, HERSMAN, and HIGGINS concurred in this recommendation.

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By: Mark V. Rosenker
Acting Chairman