Hampton Roads Interchange

April 2003

CASE STUDY: HEAT-STRAIGHTENING OF A COLLISION-DAMAGED BRIDGE BEAM WITH MULTIPLE COVER PLATES

Location:
Mercury Boulevard Bridge over Warwick Boulevard
City of Newport News, Virginia

What this is: An emerging technology.
What this is not: Mechanical bending.

Often, municipalities are faced with the reality of repairing a bridge beam after an over-height vehicle has damaged it. Currently, there is little information available and even fewer past experiences to rely on to make safe, cost-effective repairs. This article was written with the intent to convey to others interested the concept of heat-straightening damaged beams. There are no known resources describing the process to heat-straighten the type of beam described in this article. This is not a technical review but includes enough information to generally describe the process and its advantages.

Introduction

Bridge engineers are constantly encouraged to produce cost-effective solutions for various repair projects. With federal, state and local transportation agencies facing historically large budget cuts, any new work is under intense scrutiny. In addition, projects initiated due to damage or unscheduled maintenance are typically not included in budgets, further taxing strained funding resources. Money that was earmarked for sorely needed planned work now has to be shifted to pay for repairs.

The following case study examines how an emerging technology (heat straightening) was utilized to save the client a great deal of money over an industry-standard repair method (beam and deck replacement) and reduce the long-term concerns developed from previously acceptable solutions (hot mechanical bending).

Background

In April of 2002 a mechanical equipment hauler heading southbound on Warwick Blvd. impacted the first interior beam on the south side of the Mercury Blvd. Bridge in Newport News, Virginia. This collision resulted in a moderately severe bend in the bottom of the beam; approximately 9 inches out from its original position, with a well-defined horizontal yield line along the mid-depth of the 36-inch deep beam.

Strong-back beam support on bridge deck

The length of damage was in excess of 12 feet and involved tearing and bending of auxiliary steel framing and reverse bending in adjacent areas of the beam.

Immediately after the incident a professional team of engineers from MMM Design Group in Norfolk, Virginia, at the direction of the City of Newport News, was on site assessing the damage, evaluating the short and long-term concerns and developing

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President's Corner

Bekki Jucksch, P.E.,
Transportation Project Manager
Kimley-Horn and Associates, Inc.

As we near our third anniversary ASHE-GHR proudly maintains the largest membership in our Region with just over 100 members. It is you, the membership, that makes ASHE-GHR what it is today and what it will continue to become. And it is you, the membership, that has benefited, and will continue to benefit, from our programs and grass-roots efforts. As a *group* we give voice to our industry's challenges and opportunities. As *individuals* we come together to lend the group its strength and resolve. Not unlike in many aspects of life, the philosophy of "give and you shall receive" certainly applies here.

In that regard, my leadership term comes to a close in May. It has been a challenging and enjoyable year. I would like to take this opportunity to thank all of those individuals that have taken an active role in giving of themselves to help make ASHE-GHR a growing and vital organization. Durk Krone and Charlie Reid once again contributed hugely behind the scenes in their roles as Secretary & Treasurer. Rich Clifton offered invaluable guidance as Past President and often kept me straight with the voting procedures. A warm thank you is extended to the Board members mentioned above as well as Camille Kattan, Tim Brown, Bill Mackey, Mike Prezioso, Bob Johnson, Jim McCarty, Jane Wimbush, Melanie Grissom, and Mike Tugman. Your free-spoken opinions and ideas were instrumental in guiding our section through the year. Shannon West, officially Public Relations Chairperson, has contributed in so many ways, I can only say … Thank you for everything. And last but not least, thank you to John Harman (facilities chairperson), Clay Massey (scholarship chairperson) and all of the committee members. Without the combined contribution of each of you ASHE-GHR could not and would not prosper. Your support has been greatly appreciated. I am proud and honored to have had the opportunity to have served ASHE-GHR and each of you over the past year. I wish Camille Kattan, my successor all the best and know that he, too, will receive the same tremendous support that I received.

May Business Meeting

The May business meeting will feature Jeff Florin the Chief Engineer for the Virginia Port Authority will be making a presentation on How the Port affects Transportation in Hampton Roads as well as talking about up coming expansion. Following Mr. Florin's presentation we will have the Treasurer's report, brief Committee reports, the presentation of the scholarship, elections, the oath of office, and the closing by the new President. The meeting will be held, Tuesday, May 20, 2002 at the Grate Steak in Chesapeake. Social hour (cash bar) begins at 5:30 followed by dinner at 6:30.

Volunteers Needed

We are preparing the committees and recruiting volunteers for the upcoming year. More information will be coming soon. However, begin thinking about what you get out of your ASHE membership. You only get what you put into it. Working on a committee or helping to plan an event is a very rewarding experience. Plan on getting involved this year and serving *your* ASHE section. For more information on committees, contact Bekki Jucksch or Camille Kattan.

repair alternatives. It was determined that the damage posed no immediate risk to the public and traffic was diverted from the

Welder's setup below bridge deck

southern side of the bridge. The next step was to choose a repair alternative.

Previous to this project, the Commonwealth of Virginia, through the Virginia Department of Transportation (VDOT) along with many other states, accepted mechanically bending the beam by heating it to a maximum temperature and physically bending it to its original position by applying heavy jacking forces. This method, although conducted quickly and accurately, potentially introduced long-term hidden damage to the beam from excessive jacking forces which could lead to a sudden brittle failure of the beam.

Another alternative was to remove the beam and portions of the deck and auxiliary framing, as required, and replace them in kind. The majority of beams struck in a vehicle collision are the fascia (exterior) beams. This solution is costly for fascia beams and often more so for an interior beam, as was the case for this project, requiring temporary support of exterior portions of the deck and large, long-term delays to traffic.

Before considering the next alternative, more details of the bridge need to be discussed. During the labor-rich, material-poor era of the mid to late twentieth century, bridge designers sought to use as little steel as possible to effectively carry traffic with no excess material. A method often used was to weld steel plates to the bottom of the main load carrying steel beams in critical areas. They often would not run the full length of the beam, as this would not be required for strength. Typically, they were centered in the middle of the span, adding extra strength where there was the greatest stress. Usually, a single cover plate was placed on the bottom of the beam. Occasionally, a second smaller cover plate was placed under the first to reach the optimal design. This was the case for this project. Since welding and ironwork in general was relatively inexpensive, the use of cover plates was the norm.

Often, beams designed with cover plates were built during a time when compositely constructing the deck was not considered. Therefore the beam could be manipulated (or replaced) without a great deal of consideration of the concrete deck. In fact, a beam could simply be replaced by temporarily removing traffic and shoring the deck. This is often the most favorable solution for a non-composite superstructure.

In the case where beams are compositely connected to the concrete deck slab by steel studs, an emerging technology, heat-straightening the beam in place, has become a viable solution and was chosen for this project. A potential hindrance to the complete success of this process was the presence of the second bottom flange cover plate in the damage yield zone.

Heat-Straightening Process

For this project, a specific "yield zone" was determined and marked on the beam with chalk. This area of the beam is where the steel was permanently bent due to the collision. It is also known as plastic deformation. Other areas of the beam experienced elastic deformation: where bending occurred but the steel returned to its original position. The starting and ending points where the bottom of the beam no longer was straight was determined by pulling a string along the straight portions of the beam (or from bearing to bearing) and measuring the extreme distance away from the string.

Weak axis yield of bottom flange

Often the web bend is elastic, with residual stresses developed that are relieved once the bottom flange is straightened. Residual stresses are localized induced internal stresses that remain until external restraints are removed. A simplified example is a rubber band pistol. When the rubber band is stretched, stresses are developed. Once the trigger is released, these stresses are relieved. The bend in the beam follows a curve along the surface of the web, much like bending a sheet of paper.

Occasionally, the web will develop a plastic bend where a hinge point develops along a line at a certain depth of the beam, establishing a permanent deformation. This occurred in the subject bridge beam, creating an obvious yield zone. It is important to define the yield area because heating areas out of the yield zone is ineffective and possibly counter-productive.

Once the damaged areas of the beam are determined, heating patterns are predicted and repair scheduling is conducted. Generally, heating begins around the impact area to acclimate the beam to the process and relieve any residual stresses. To straighten the bottom flange, a restraining jacking force was calculated to only resist any outward movement of the beam. Vee shapes, described later, are then chalked on the flange. In the case of one cover plate, the chalked vee is replicated on the top of the bottom flange and on the bottom cover plate.

Properties of Steel

Steel can be heated to roughly 1300 degrees Fahrenheit with no detrimental long-term effects. This temperature is known as the lower phase transition where, depending on carbon content and other miscellaneous alloys, heating steel above this amount will begin to change the properties of the steel, changing the strength characteristics and degree of brittleness.

For this process, a limit of 1200° F was used and temperature crayons were utilized to verify that this temperature was not exceeded. (Temperature crayons will melt at specified temperatures, indicating a measured "heat" of the steel.) Naturally, steel expands when heated and contracts when cooled.

In general, heat straightening employs the natural tendency of steel to contract while

Yield zone heat application area

it cools. If steel is heated using the shape of a vee and expansion is resisted by jacks and the surrounding cool steel, the open end of the vee will tend to contract as it cools and the steel will bend in the direction of the closed end of the vee. For any project, specific heat patterns are determined and restraining jacking forces are calculated to resist expansion. If properly performed, during the cooling time between heat cycles the beam will return to its original position with no excess jacking required.

View of Beam BEFORE Repair

Experience

An option for this project was to remove the bottom cover plate to ensure a successful operation, however in order to proceed as economically as possible, it was first attempted to straighten the beam with the second cover plate attached. This proved to be a hindrance, as the space between plates acted as a heat sink: not enough heat reached the interior plate to be effective.

View of Beam AFTER Repair

At this point, provisions were made to remove the bottom cover plate in the yield zone by first placing false work on top of the deck to alleviate the dead load deflection from the bottom of the beam. False work could have been utilized below the bridge under the right circumstances, however with heavy traffic conditions it is advisable to attempt to support the weight carried by the beam from above. This method only requires the closure of one lane of traffic, and more commonly this is the shoulder or weaving lane. Once the bottom cover plate was removed, the heat straightening resumed and significant movement was noted. Accepted FHWA laboratory standards were followed and the entire operation was a success, saving dollars for the City and public time spent in traffic.

Although a similar method is used to create curves in new beams, as a newer technology, only a handful of active bridges in a few States have had beams straightened by this method. According to Federal Highway Administration officials, heat-straightening a bridge beam with two cover plates had never before been attempted. No prior experience was available as a guideline, so lessons were learned in the field.

Advantages

- Eliminates excessive jacking forces (which may lead to brittle cracks).
- Reduces traffic delays.
- Saves money.

Conclusion

This case study is but one example of the limitless number of applications for the steel heat-straightening process. For further information as related to straightening bridge beams, the latest information can be found through the United States Department of Transportation Federal Highway Administration in publications such as *Heat-Straightening Repairs of Damaged Steel Bridges: A Technical Guide and Manual of Practice*, which was employed in this case study.

This article was written byShannon M.B. Turner, EIT and Philip D. Quillin, II, PE. They are both engineers with MMM Design Group in Norfolk.

Nominations for 2003-2004 Board

Below is the Slate of Officers for the 2003-2004 calendar year. This slate was developed by the nominating committee based on an expression of interest from these individuals to serve in a leadership capacity in the organization.

The slate of officers stands as presented by the nominating committee. The agenda for the May 20th membership meeting is as follows:

- √ presentation of nominations
- √ election
- √ installation of officers
- √ committee reports.

The Officers and Board of Director nominations for this election are:

- *President: Camille Kattan*

Camille is the principal of G E T Solutions, Inc. located in Virginia Beach, a Geotechnical Engineering firm that he started in the year 2000. Camille has made Hampton Roads his home since 1987, after spending nearly 4 years working with the NCDOT in Raleigh as a Soils Engineer. He earned a Bachelors in Civil Engineering and a Masters in Geotechnical Engineering from West Virginia University. Camille is a charter member of the ASHE GHR Section and has previously served as a Regional Director and 1st Vice President, and he is also a member of ASCE and VSPE. Camille lives in Virginia Beach with his wife Marie and their 2 kids, Jacob 5 and Danielle 2, and he enjoys golf with its ups and downs and fishing the Chesapeake Bay waters where he is much disliked by the fish population.

- *First Vice President: Mike Tugman*

Mike has 16 years of experience in highway and civil design and is currently a Project Manager in the Transportation Section of HDR in Norfolk. After graduating from North Carolina State University in 1987 with a Bachelor's of Science Degree in Civil Engineering, he moved to the Tidewater area to begin his career with HDR. Mike was named Professional Associate at HDR in 2001 and currently serves on the ASHE Board of Directors. He enjoys golf, racquetball and softball, and is the Chairman for the annual ASHE Columbus Day Classic scholarship golf and tennis tournament. Mike lives in Virginia Beach with his wife Michelle, and daughters Ashley (14) and Brooke (12).

- *Second Vice President: Unwanna Bellinger*

Unwanna Bellinger works for the Virginia Department of Transportation in the Hampton Roads District where she serves as the District Planning Engineer. She is responsible for the management of the District Transportation Planning Program, Land Development Program, HOV and Transit System Planning, Bicycle and Pedestrian Planning and she is involved in numerous other road Project Development activities. She has occupied her current position for 4 years. She has been with VDOT or 6 years.

Unwanna holds a Bachelor of Science degree in Civil Engineering from South Carolina State University and a Masters in Public Administration from Old Dominion University. Her professional memberships include the American Planning Association, American Society of Highway Engineers, the American Society of Public Administration, and the Virginia Section of the Institute of Traffic Engineers.

Additionally she holds memberships in Pi Alpha Alpha National Honor Society for Public Affairs and Administration as well as Beta Gamma Sigma National Honorary Business Society. She is currently pursuing a Ph. D. in Public Policy and Administration at Virginia Commonwealth University. A native of Orangeburg, South Carolina, Unwanna enjoys traveling, planning parties, and playing golf.

- *Secretary: Durk Krone*

Durk Krone is serving as Branch Manager for Hardesty & Hanover's mid-Atlantic engineering services in the firm's regional office in Norfolk. Mr. Krone, recently promoted to

Associate, has 21 years experience in bridge and tunnel engineering. Durk was raised in Buffalo New York where he earned his BSCE and MSCE at the State University of New York at Buffalo. Durk is a resident of Chesapeake where he is a baseball coach and attends Atlantic Shores Baptist Church. Durk and his wife, Laura, have four children; Taylor (9), Connor (7), Madison (4), and Landon (3).

- *Treasurer: Charlie Reid*

Charlie is the Chief Structural Engineer and President of Reid Structure & Bridge, Inc., a firm that he founded in 1984. He has 36 years experience in the private practice of structural engineering with much of it devoted to the design and management of highway bridges. His expertise also includes water front engi neering and building structures. Charlie earned both his BSCE and MSCE from Virginia Tech and is an active sup porter of Hokie football. When not attending a football game in Blacksburg, he is often enjoying a round of golf. Charlie resides in Virginia Beach with his wife, Connie. Charlie has served as ASHE treasurer for the past 3 years.

- *Director: John Harman*

John G. Harman, P.E. is a registered professional engineer engaged as a Transportation Senior Project Engineer for Gannett Fleming, Inc, Newport News. He has thirty years of transportation, municipal and utility design experience with consulting firms located in the states of Maryland, Louisiana, West Virginia and the commonwealth of Virginia. John is an associate member of ASCE, former member of VASITE and Va. Tech Alumni Chapter President- Maryland. John has been living in tidewater Virginia since 1992 and is married with one son, currently attending Tidewater Community College. John's spare time is occupied by duties of District Officer in Toastmasters District 66 and an occasional game of tennis.

- *Director: John Mason*

John's education includes a BS in Geology from Old Dominion University 1971 and a BS in Civil Engineering With High Distinction from The University of Virginia 1977. He worked in geotechnical engineering and general civil engineering early in his career and has focused on transportation for the past 20 years. Some noteworthy projects bearing John's seal include Independence Boulevard from Holland Road to Haygood Road in Virginia Beach and the Virginia Inland Port in Front Royal, Virginia. Professional affiliations include ASCE, VASITE and ASHE. He is currently Chairman of the Civil and Environmental Engineering Visiting Council at Old Dominion University.

- *Director: Bob Scott*

Robert (Bob) T. Scott, Jr. works for the Hampton Roads District where he serves as assistant to the District Construction Engineer. He is responsible for the coordi nation of preliminary engineering func tions, public involvement, management of the 24-month construction delivery (Dashboard) and post construction pro grams in the district. He is a graduate of Norfolk State University with a B.S. degree in Business Management and has 30 years experience in roadway design and project management. A native of Suffolk, Bob enjoys any outdoor activity and is married to Judy. They have two sons, Robert III and Brian.

- *Regional Director: Shannon West*

Shannon West is the Director of Marketing for Hoggard/Eure Associates. A resident of Portsmouth, she is a 1998 graduate of Christopher Newport University with a BS in Computer Science and received her MBA from Troy State University in 2001. She has been the public relations chair for the past two and half years with ASHE. Shannon will serve as the President of the Virginia Chapter for SMPS for 2003-2004. She is also actively involved in HRACRE and the Portsmouth Chamber of Commerce Education Committee. When not working or attending professional organziation meetings, she isbusy planning her October wedding to Carey Lee, reading, attending NASCAR races and traveling back and forth to her hometown of Wakefield to visit family.

Century Club Members

Century Club Members support the endeavors of ASHE through financial support. Each member will be listed in future newsletters, as well as included on all mailings. If you are interested in becoming a member, send a check for $100 or more to ASHE. For more information, contact Tim Brown at MMM Design Group (623-1641).

- Aquarius Engineering
- Clark-Nexsen, P.C.
- Foundation Engineering Science, Inc.
- Gannett Fleming
- G E T Solutions, Inc.
- Hardesty and Hanover
- Hayes, Seay, Mattern and Mattern
- Hoggard/Eure Associates, P.C.
- Jacobs Engineering Group, Inc.
- Kimley-Horn and Associates, Inc.
- Kubilins Transportation Group
- McDonough Bolyard Peck, Inc.
- MMM Design Group, Inc.
- Parsons Brinckerhoff Quade & Douglas, Inc.
- Precision Measurements, Inc.
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- Reid Structure and Bridge
- Rummel, Klepper & Kahl, LLP
- Suburban Grading
- URS
- Vanasse Hangen Brustlin, Inc.
- Waterways Surveys& Engineering, LTD.
- Woolpert, LLP

Member News

Larry Moore with Gannett Fleming has been named a Senior Associate with the firm. Rich Clifton has been named an Associate of the firm. Congratulations on this achievment!

Tim Brown, P.E. has been promoted to Vice President. He has been with MMM Design Group for 5 years. Way to go Tim!

Lindsay Dixon with Gannett Fleming has recently gotten engaged. She and Hunter Birckhead are planning a September wedding in Chesapeake. Congratulations to you both!

Welcome Chris Hasty! He has recently joined ASHE. He is a project engineer with MMM Design Group. He is a 1994 graduate of ODU.

"Traffic Stoppers" will feature professional and personal accomplishments of Section members, as well as new member information. Submit information to: Shannon West, 757/484-9670

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