VERMONT

Agency of Transportation

Covered Bridge Collision Prevention Measures

BACKGROUND

Covered bridges frequently have lower overhead clearance than other highway structures, and thus are at greater risk of being struck by over-height vehicles. These collisions are not always well documented and sometimes not discovered until the next bridge inspection identifies the damage, so the total cost is unknown. Preventing bridge collisions is important from a safety perspective and due to the historical significance and presence of these structures in Vermont. There are over 100 covered bridges in the state with the oldest dating back to the mid-1800s.

STANDARD MEASURES

The standard signage for covered bridges includes low clearance warning signs, lane alignment or width information signs, and weight limit signs, depending on the bridge configuration. Any limitations shall be posted approximately 100 feet in advance of the bridge approaches and at intersections to enable operators to turn around or detour if needed. Signage shall be in accordance with the FHWA Manual on Uniform Traffic Control Devices (MUTCD), and the minimum height and width as identified by the Agency's Bridge Management and Inspection team. Low clearance signs are used when vertical clearances are less than 14 feet 6 inches. Additional information about vertical and horizontal clearance can be found in the appendices. To request signs to implement these standard measures, towns should reach out to the appropriate VTrans Maintenance District (https://vtrans.vermont.gov/operations/districts).

OPTIONAL ADDITIONAL MEASURES

There are several options to choose from to help protect covered bridges and there are many factors to take into consideration. Some of the most important factors to account for are historical significance, protection needs, and collision history; bridges are often hit multiple times and a history of collisions could indicate a greater need to prevent them in the future. See Appendix IV for additional information located in the Pennsylvania DOT document.

If it is determined that the standard signage is not providing adequate protection, there are three main types of countermeasures: passive, mitigation/sacrificial, and active. The National Cooperative Highway Research Program (NCHRP) indicates that passive measures offer a small increase in incident prevention, mitigation/sacrificial offer a moderate increase, and active countermeasures provide the greatest effectiveness in preventing incidents. Countermeasures can be combined to increase their efficacy. These countermeasures may present risk, hazard or other liability to the structure, the traveling public or the town if implemented incorrectly. Before any countermeasures are constructed, Towns should consult with their engineer and/or Legal Counsel to ensure treatments are applied appropriately.

Passive countermeasures are changes that help drivers make decisions but are static and do not change. These countermeasures consist of signage improvements, reflective markers around the vehicle opening of the bridge, and road markings, where applicable. They are the least costly and easiest to implement but offer the smallest increase in collision prevention.

Mitigation and sacrificial countermeasures are passive additions that serve two different but similar purposes. Mitigation countermeasures are nonrigid items intended to give notice to the driver such as hanging chains or clearance bars, sometimes referred to as headache bars (Image 1). These changes can be harder to implement but offer the driver tactile feedback on their vehicle height. They are intended to be installed in advance of the bridge or in the bridge portal, and to hang at the same height as the bridge so that drivers contact the device if their vehicle is larger than the available clearance. Hanging chains and clearance bars will not completely prevent a vehicle from attempting to enter a bridge but are designed to be hit by over-height vehicles to get the drivers attention and cause them to stop before the vehicle can cause damage to the bridge. Sacrificial countermeasures on the other hand, are rigid steel structures meant to protect the bridge, usually called overhead impact bars, or “crash” bars. (Image 2). Overhead impact bars are meant to be hit by over-height vehicles and take the impact instead of the bridge but are typically a last resort type of countermeasure. Other measures included in this category include rumble strips and extended curbs or road narrowing to help the driver center their vehicle on the bridge to ensure they are provided the highest clearance.

Image 1: Clearance Bar

Image 2: Overhead Impact Bar

Active countermeasures are the most technically advanced, the most challenging to install, and have the highest installation expense as well as the highest ongoing maintenance cost. Some of the more popular active countermeasures provide real-time early warnings to drivers with activated message boards or warning lights using radar, video, or laser-based systems to detect over height vehicles and warn drivers that their vehicle exceeds the clearance available at the bridge. While these countermeasures can be effective, towns will need to determine if active countermeasures are appropriate. Towns should consider the cost to install and maintain the devices as well as the potential aesthetic impact on the area before deciding to pursue active countermeasures. If active countermeasures are determined to be appropriate but the cost seems too high, the town might consider weighing the cost of the countermeasure with the cost to repair a bridge that has been hit. Georgia DOT completed a study in 2017 which includes a table of recommended options for the more advanced systems which can be found below in Appendix III, the entire study can be found linked in Appendix IV.

The most challenging part of using an electronic countermeasure is the reliance on power. Each location would need to be evaluated for the availability of power. As an alternative to hard-wiring these devices, a solar panel may be used. However, Vermont poses challenges with the reliability of solar devices because of snow and shade. Municipalities would be responsible for maintenance of these systems if they are installed.

RESOURCES

- FHWA Covered Bridge Manual
  https://www.fhwa.dot.gov/publications/research/infrastructure/structures/04098/04098.pdf
  This manual covers general terminology and historic development of covered bridges.
- Manual on Uniform Traffic Control Devices (MUTCD)
  https://mutcd.fhwa.dot.gov/pdfs/2009r1r2/pdf_index.htm
  The MUTCD is recognized as the national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel to obtain basic uniformity.
- Images
  https://lancasteronline.com/news/lancaster-county-installs-headache-bars-to-protect-22-covered-bridges/article_db3b2c91-2e63-5b2b-95c3-15ecd9841187.html
  https://bridgehunter.com/nc/durham/bh50197/
- See Appendix IV for additional resources

APPENDIX I:

W12-2

W12-2a

Section 2C.27 Low Clearance Signs (W12-2 and W12-2a)

Standard:

01 **The Low Clearance (W12-2) sign (see Figure 2C-5) shall be used to warn road users of clearances less than 12 inches above the statutory maximum vehicle height.**

Guidance:

02 *The actual clearance should be displayed on the Low Clearance sign to the nearest 1 inch not exceeding the actual clearance. However, in areas that experience changes in temperature causing frost action, a reduction, not exceeding 3 inches, should be used for this condition.*

03 *Where the clearance is less than the legal maximum vehicle height, the W12-2 sign with a supplemental distance plaque should be placed at the nearest intersecting road or wide point in the road at which a vehicle can detour or turn around.*

04 *In the case of an arch or other structure under which the clearance varies greatly, two or more signs should be used as necessary on the structure itself to give information as to the clearances over the entire roadway.*

05 *Clearances should be evaluated periodically, particularly when resurfacing operations have occurred.*

Option:

06 The Low Clearance sign may be installed on or in advance of the structure. If a sign is placed on the structure, it may be a rectangular shape (W12-2a) with the appropriate legend (see Figure 2C-5).

APPENDIX II a:

W5-1

W5-2

W5-3

Section 2C.20 <u>NARROW BRIDGE Sign (W5-2)</u>

Guidance:

01 *A NARROW BRIDGE (W5-2) sign (see Figure 2C-5) should be used in advance of any bridge or culvert having a two-way roadway clearance width of 16 to 18 feet, or any bridge or culvert having a roadway clearance less than the width of the approach travel lanes.*

02 *Additional emphasis should be provided by the use of object markers, delineators, and/or pavement markings.*

Option:

03 A NARROW BRIDGE sign may be used in advance of a bridge or culvert on which the approach shoulders are narrowed or eliminated.

Section 2C.21 <u>ONE LANE BRIDGE Sign (W5-3)</u>

Guidance:

01 *A ONE LANE BRIDGE (W5-3) sign (see Figure 2C-5) should be used on two-way roadways in advance of any bridge or culvert:*

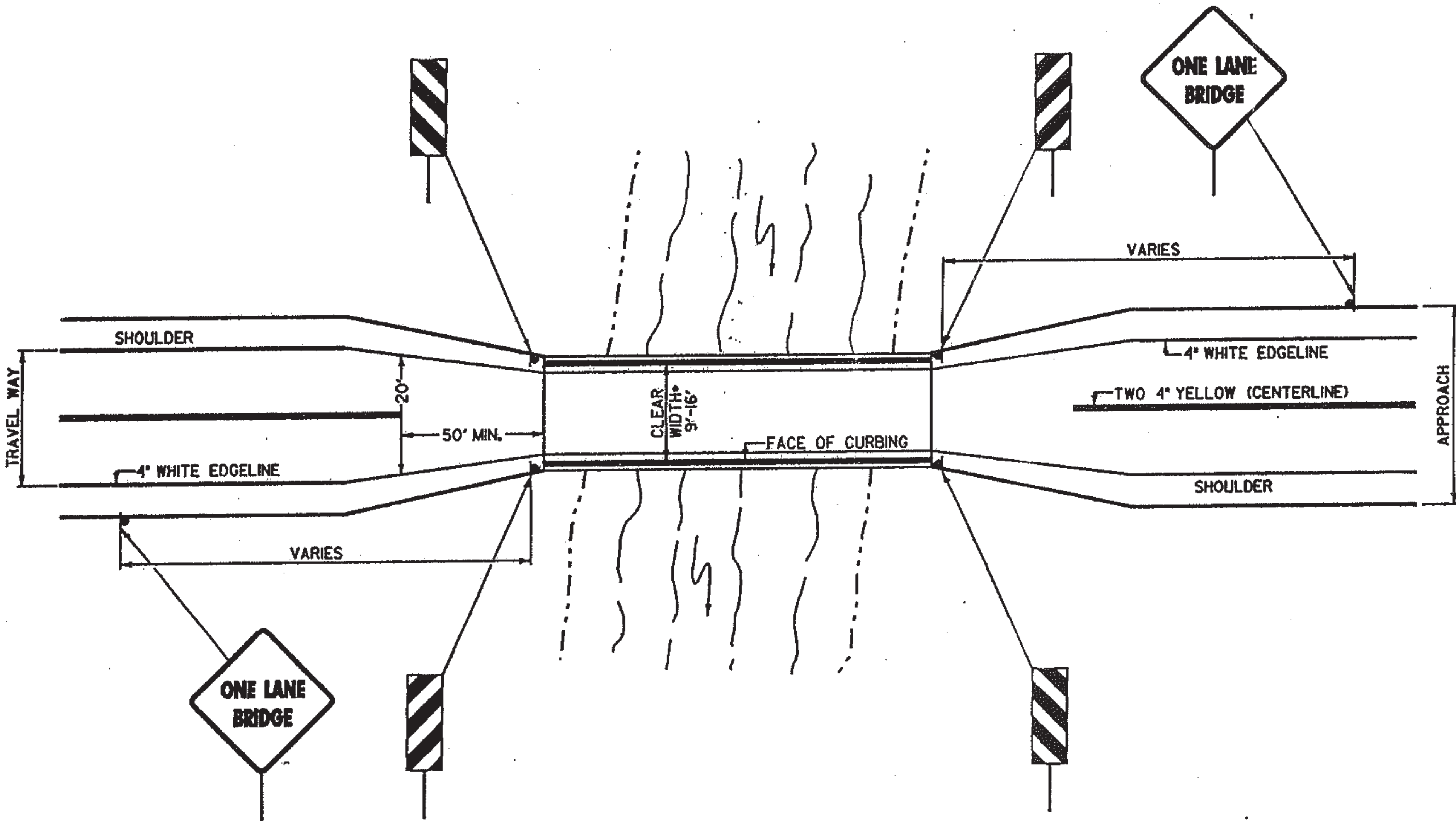
- *A. Having a clear roadway width of less than 16 feet, or*
- *B. Having a clear roadway width of less than 18 feet when commercial vehicles constitute a high proportion of the traffic, or*
- *C. Having a clear roadway width of 18 feet or less where the sight distance is limited on the approach to the structure.*

02 *Additional emphasis should be provided by the use of object markers, delineators, and/or pavement markings.*

05 **When the W14-1 or W14-2 sign is used, the sign shall be posted as near as practical to the entry point or at a sufficient advance distance to permit the road user to avoid the dead end or no outlet condition by turning at the nearest intersecting street.**

06 **The DEAD END (W14-1a) or NO OUTLET (W14-2a) signs shall not be used instead of the W14-1 or W14-2 signs where traffic can proceed straight through the intersection into the dead end street or no outlet area.**

APPENDIX II b:



ONE LANE BRIDGE TREATMENT

NOTES:
1. NO CENTERLINE ON ONE-LANE BRIDGE.
2. TAPER EDGELINES ON APPROACH AT 1':25'.
3. TYPE III OBJECT MARKERS REQUIRED.
4. "ONE LANE BRIDGE" SIGNS LOCATE AS PER MUTCD TABLE II-1.
5. CENTERLINE STOPS WHEN TRAVEL WAY EQUALS 20'.
6*. MAY BE >16' IF DESIGNATED BY PROPER AUTHORITIES.
7. BRIDGE TO HAVE NO EDGELINES IF CLEAR WIDTH IS <11'.

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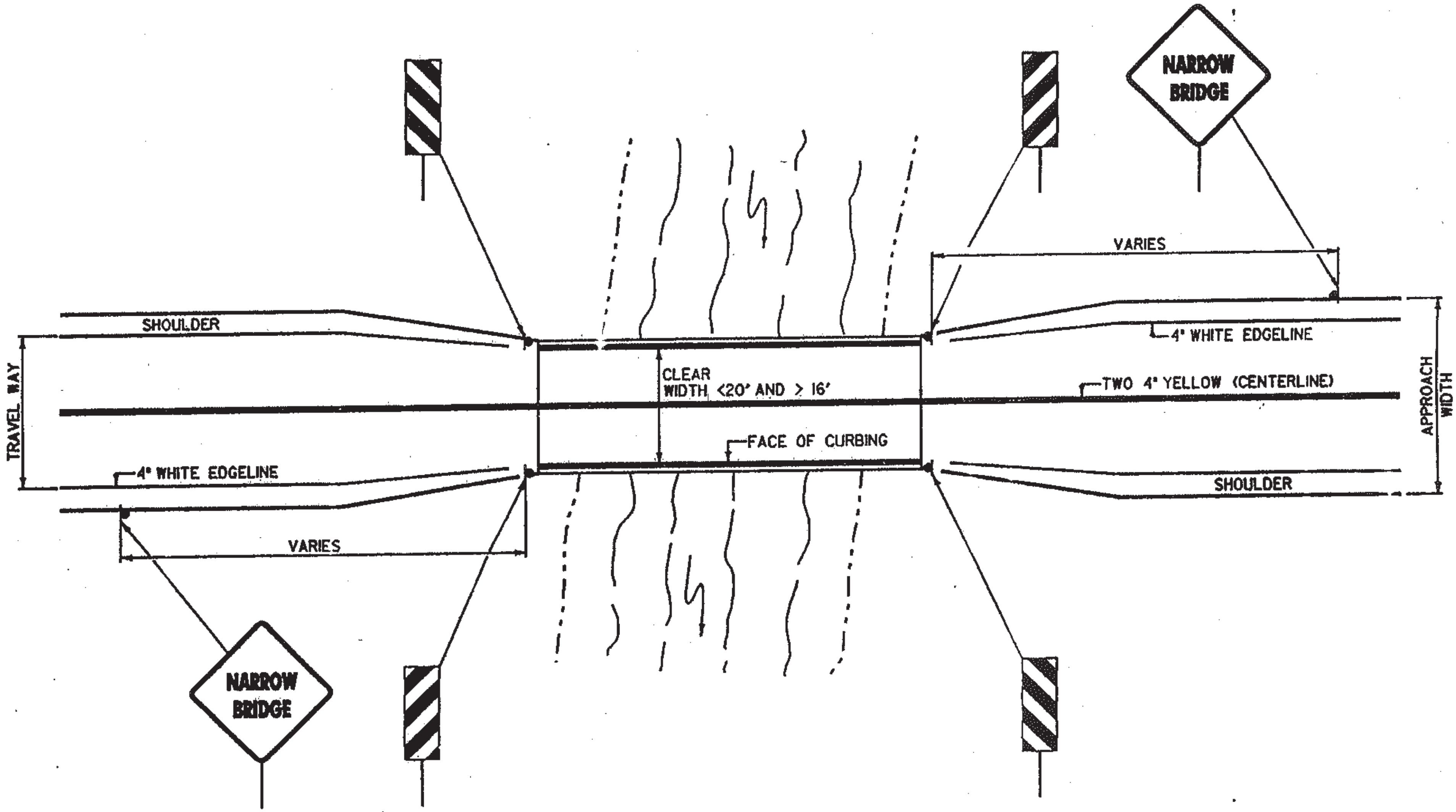
lparm name : bridges.l
03/21/95

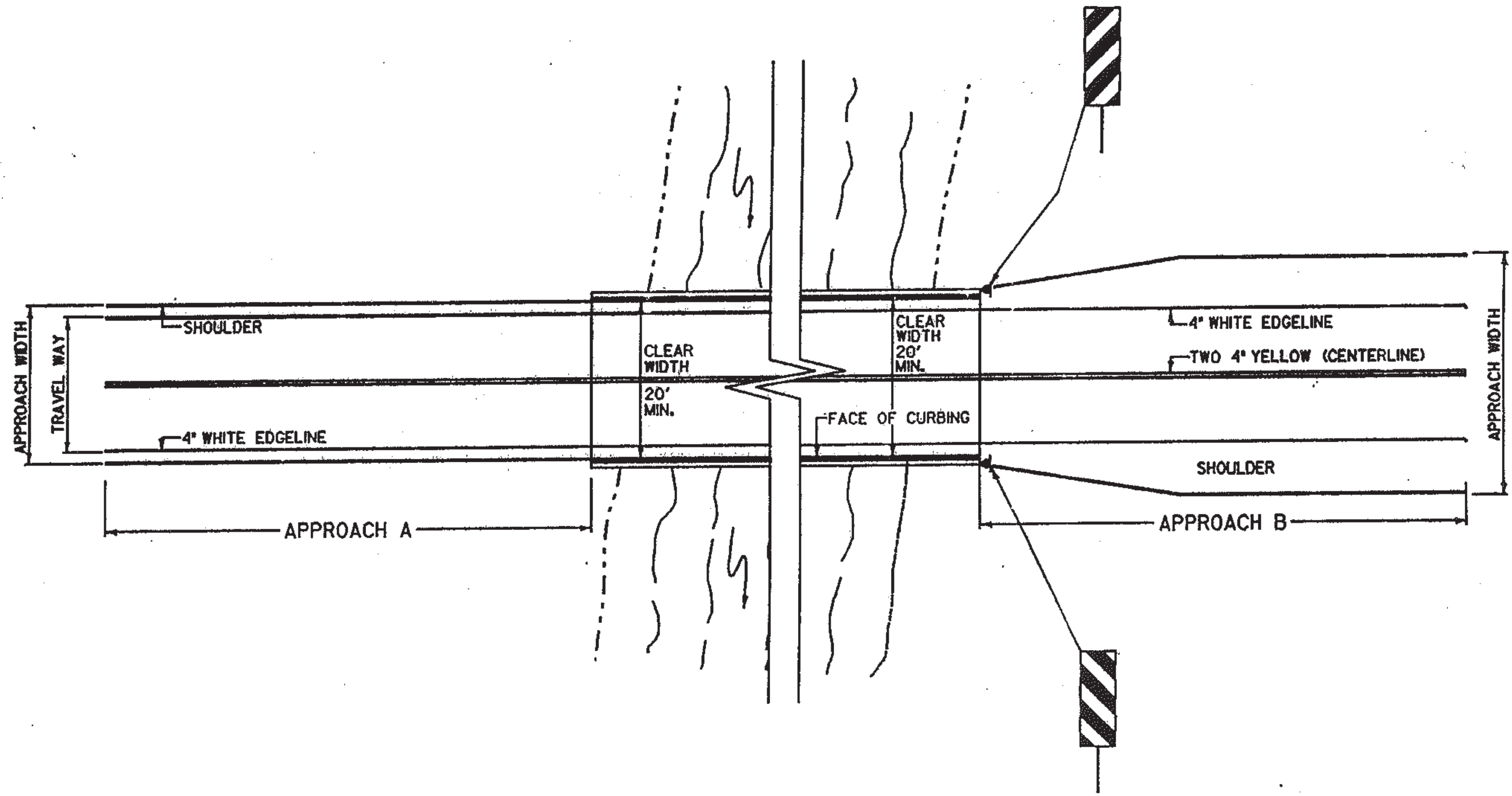


NARROW BRIDGE TREATMENT

CLEAR WIDTH LESS THAN 20'

NOTES:
1. CENTERLINE THROUGH BRIDGE.
2. NO EDGELINE THROUGH BRIDGE.
3. TAPER EDGELINES ON APPROACH AT 1':25' IF NEEDED TO OBTAIN EDGELINE OFFSET OF ONE FOOT FROM CURB.
4. TYPE III OBJECT MARKERS REQUIRED.
5. "NARROW BRIDGE" SIGNS LOCATE AS PER MUTCD TABLE II-1.

file name : /traf/jss/bridges.dgn/
iparm name : bridges.1
03/21/95



TWO-WAY BRIDGE TREATMENT

CLEAR WIDTH 20' OR GREATER

NOTES:
1. CENTERLINE THROUGH BRIDGE MAY BE DASHED FOR PASSING IF APPROPRIATE.
2. EDGELINES MATCH APPROACHING ROADWAY OR TAPER AT 1':25' TO MATCH.
3. TYPE III OBJECT MARKERS REQUIRED WHEN APPROACH WIDTH IS GREATER THAN CLEAR WIDTH AS SHOWN IN APPROACH B.

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03/21/95

APPENDIX III:

TABLE 6
Recommended Options – Systems and Vendors

Product Name	Vendor/ Manufacturer	Cost (approximation or quote)	Performance
3M Fixed ALPR Camera ***(camera-based only)***	**3M**	Two options: P392 at a list cost of $9,000 per camera; P492, $11,000 per camera. Single termination boxes, $1,300, and mounting brackets, $850 (cameras are connected to termination boxes that operate on 15V or 48V)	High-quality image resolution and accurate performance; metal housing for longevity in a variety of operating environments
TIRTL ***(laser-based, IR detector)***	**CEOS (Control Specialists are the US distributor)**	$14,430, less accessories. TIRTL riser and L-bracket (pair), $510; install fittings, $2,180; additional items, such as power supply, Ethernet cables, and signal timer, up to $825 (quotation from vendor: total $19,000, furnish only, includes $750 shipping, taxes to be added)	Low-power consumption; rugged, impact and corrosion-resistant construction; rated for industrial temperature ranges; IP67 immersion and ingress resistant; detects vehicles traveling up to 155 mph; rejects birds, leaves, rubbish; all features as per standard TIRTL with extra overheight alarms
ELTEC Warning and Caution System ***(combined system)***	**ELTEC**	Up to $25,000, depending on the case (quote provided on request)	No functionality problems reported; very little maintenance (annual inspection required)
BlinkerSign® (High-Speed Overheight Warning System) ***(multibased system)***	**TAPCO**	The company provided a sales quote to the research team: $25,660, "furnish only", installation not included	No sensitivity problems; independent of power grid - effective even during power outages; sensor height tailored to each system; records the number of activations
Overheight Vehicle Detection System (OVDS) ***(combined system)***	**TRIGG Industries**	Range from around $5,000 for the simplest traffic models to $15,000 for the most complex	Alerts and directs the driver via warning signs and warning bells to take corrective action; provides secondary warning beyond existing signage in the interest of public safety; proven to minimize/eliminate the occurrence of accidents and incidents caused by overheight vehicles (see appendix C for catalog information)

APPENDIX IV:

Covered Bridge Collisions
Literature Search completed by VTrans Research (Tanya Miller and Emily Parkany, January 2022)

There are three types of preventative systems:

- Active – these include things like early warning detection systems both inside and outside of vehicles
- Passive – these include measures like signage, bridge markings and variable message boards
- Mitigation or Sacrificial – these include crash beams, hanging chains and headache bars

The literature includes few mentions of route guidance systems such as Waze but covered bridge and bridge strike news articles suggest that the collisions may be related to navigation systems. Below you'll find notes related to items found related to bridge strikes including Covered Bridge Protection Guidance from PennDOT; a current NCHRP project literature review; warning system evaluation from GA, recent papers from the UK and NZ; and specific case studies from NY, AK, WA and MN.

PennDOT Structures Procedures, Design, Plans Appendix S Covered Bridge Protection Guidance (2019)

https://www.dot.state.pa.us/public/PubsForms/Publications/PUB%2015M.pdf

- PennDOT Chief Bridge Engineer provided us (1/21/22) with link to the Design Guide and told us to look at Appendix S and told us that PennDOT (nation's largest number of covered bridges) has installed a few "headache bars"
- Choosing a mechanism for covered bridge protection involves several factors: type of protection, frequency of impact, historic significance of the structure, and external needs of the protection system
- Types of protection: increased signage, pavement markings, increased curb widths, rumble strips, headache bars, warning lights, advanced electronic equipment (cameras, laser vertical detection devices)
- All systems should be evaluated based on historic significance of the structure and any past history of bridge damage
- Where possible, consider providing wide approaches to allow overheight/overweight vehicles to turn around before getting to the bridge – turnaround should be places in advance of rigid headache bars

NCHRP 08-139 Guide for Preventing and Mitigating the Risk of Bridge and Tunnel Strikes by Motor Vehicles: (2021 Literature Review)

https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4950

- NCHRP Program Manager provided the literature review to us of this project that started October, 2021. This is not available online.
- 3 protection schemes – passive (signage, variable message signs, bridge markings.), mitigation systems (crash beams, hanging chains), and active systems (early warning and detection systems both in field and in vehicle)
- Passive signage is 10-20% effective in preventing incidents, sacrificial system is 30-50% effective, active is 50-80% effective
- Cost of installing an overheight vehicle (OHV) early warning detection system (active example) is less than the cost of repairing damages from strikes
- 22 US states reported using various warning systems. 25 states don't use any warning systems

- Many states have started using warning systems with laser or infrared lights, or a patented z-pattern red/infrared dual beam array with the ability to reject ambient lights which eliminated false over-height alarms
- Can also use vision-based system – comprised of 4 processes: field of view calibration, detection, truck height measurement and warning notice
- Our lit review initially uncovered a Research Problem Statement from 2012 on Covered Bridge Collisions. This was not funded but it was submitted by the PennDOT Bridge Engineer who sent us the PennDOT Design Guide with Appendix S Guidelines for Covered Bridge Protection and led us to the new NCHRP project NCHRP 08-139 Guide for Preventing and Mitigating the Risk of Bridge and Tunnel Strikes by Motor Vehicles (started October 2021; expected completion April 2024)

GeorgiaDOT Warning Systems Evaluation for Overhead Clearance Detection (2017 report)

https://rosap.ntl.bts.gov/view/dot/31978

- Studies off-the-shelf systems to detect the heights of vehicles to minimize or eliminate collisions with roadway bridges (not necessarily covered bridges)
- Tested passive, active and combined systems
- Were having 50 collisions by overheight vehicles every year
- Suggested using 1 or 2 systems together, monitoring performance for a year
- One page summary of recommended options with 2017 prices should be extracted and provided with review (page 96 of PDF in the folder).
- No follow-on project with recommended devices.
- Alaska DOT performed an evaluation report in 2003 (Mattingly). A table of prevention methods employed by 11 states is often cited.

New Zealand – Managing Bridge Strikes from Rail to Road Bridges (2019 Australian conference paper)

https://www.eiseverywhere.com/file_uploads/c79ec26115cd9aa1f1f8d7a45d2c3775_Coleman-NZ_Transport_ManagingBridgeStrikesfromRailtoRoadBridges.pdf

- "Prevention is better than a cure". Cures protect that asset or limit the outcome.
- Use of 4 E's – Education, engineering, enable, enforcement
- Use of 4 P's – Prevention, Prosecution, Pursuit for payment, Publicity
- 32% of drivers don't know their vehicle heights, 56% didn't consider low bridges in their route selection, 10% used satellite navigation, 31% didn't get any guidance from their employers
- Recommendation – Industry to design route planning, height measurement tools, in cab low bridge warning systems, better advanced warning signs, engagement and training of industry, effective enforcement of regulations.
- Key to reducing frequency is to improve engineering of site with signage, collision protection beams, but more importantly promoting a behavioral change of both vehicle drivers and operators

University of Cambridge, UK Understanding the Problem of Bridge and Tunnel Strikes Caused by Overheight Vehicles (2016 academic paper)

[Understanding the Problem of Bridge and Tunnel Strikes Caused by Over-height Vehicles (sciencedirectassets.com)]

- Details efforts to mitigate bridge strikes where there is not enough vertical space between a rail bridge and the highway below
- Can use passive systems (signs, variable message boards, flashing signs and bridge markings, policy mandates like axle load restrictions, drivers education), sacrificial systems (crash beams, hanging headache bars or chains, road narrowing, speed bumps or rumble strips), and active systems (GPS, visual and audio warnings, overheight vehicle detection systems, early warning detection systems)
- Also need reporting systems (CCTV, weather and roadway conditions monitoring)

NYSDOT Bridge Vehicle Impact Assessment – 2012 Report

https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C_07_10_final%20report.pdf

- 3rd leading cause of bridge failure or collapse is collision damage when a vehicle or a vessel hits a bridge
- Bridge hit frequency has peaks at 14.5' and 16.5'. above 16.5' the number of bridges struck drops off sharply. 16.5' normally constructed over the interstates and state routes. 14.5' were commonly constructed over local roads
- 19 states consider overheight collisions to be a significant problem, but very few states collect data on the bridge hits
- Some states post the actual vertical clearance on warning signs, while other states under report the clearance by up to 12"
- 9 states reported installing more signs posting clearances on or in advance of bridges. 7 states increased vertical clearances by grinding pavement or raising overpasses. 3 states use overheight detection systems
- Use of early warning devices results in reduction of bridge hits
- Created bridge hits database
- Areas with significant agricultural and commercial activity have higher bridge strikes, also higher bridge strikes near the Canadian border or near cities
- 43% of crashes occurred on local roads (county, town, city and village) -figure 1-14 pg 15

Alaska DOT - Eklutna Bridge Overheight Detection System Evaluation (2006 report)

https://rosap.ntl.bts.gov/view/dot/26803

- Clearance 16'1"
- Vehicle over-height detection and warning system was installed in 2006
- Southbound lane upgraded to new signal controller, detector loops, two video cameras and a video recorder.
  - This was to reduce occurrences of false alarm and cameras provide data to determine if system is effective
  - 65% of the false alarms occurred in extreme winter weather events

        - Freezing fog from trucks' exhaust pipes when air temp is below -10, or heavy snow events.
    - System is working according to the design, warnings were issues to over-height vehicles
    - Recommendation: Blank-out signs should be moved 100 feet further downstream from its current location, cellular radio modem should be added to improve wireless communication, restore controller cabinet grounding

National Transportation Safety Board –Highway Accident Report WA Interstate 5 Skagit River Bridge Strike and Collapse (2013 report)

https://www.ntsb.gov/investigations/AccidentReports/Reports/HAR1401.pdf

- Collapse of interstate 5 Skagit River bridge following a strike by an oversize combination vehicle
- Reviewed videos from several cameras (2 building mounted security cameras, one surveillance video from car dealership, dashboard camera in Washington State Patrol car)
- Automatic permit process through Washington DOT – no WSDOT personnel reviewed the request
- No signs posted on the overhead structure, no signed posted to the right or left of the travel lanes, no signs indicating the bridge's vertical clearance
- "transforming its bridge clearance data into geospatial format and developing interactive maps for data users."
- Raised overhead clearance to 18'

University of Minnesota –Snowplow-Bridge Impact Box Warning System (2008 report)

https://rosap.ntl.bts.gov/view/dot/39481

- Snow plows use GPS technology for Automatic Vehicle Location to create collision maps.
- Prototype warning system that serves as a bridge proximity sensor will be developed to alert the plow driver that they're approaching a collision bridge
- Plows used a hardened on-board microcontroller, a GPS sensor and a box position sensor for the prototype solution