



Development of a Plan for Compliance with NCHRP 350 for Temporary Concrete Barriers

Final Report 531

Prepared by:

Muhannad Zubi, P.E.

Annette Riley

Arizona Department of Transportation / Traffic Group

2828 North Central Avenue, Suite 900, MD 063R

Phoenix, Arizona 85004

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| 16. Abstract The Federal Highway Administration (FHWA) has mandated that TCBs used on federally funded projects on the National Highway System (NHS) advertised after October 1, 2002 shall meet the requirements of NCHRP 350. The State's present TCB system design is not approved as meeting the NCHRP 350 requirements, and even with modifications it is not likely to meet those standards. ADOT and Arizona industry partners are to evaluate many key factors in the Department's effort to develop an NCHRP 350 compliance plan for TCB. Arizona intends to adopt the most valid non-proprietary TCB design, out of already approved designs, for future use in Arizona. | | | | | |
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SI* (MODERN METRIC) CONVERSION FACTORS

| APPROXIMATE CONVERSIONS TO SI UNITS | | | | | APPROXIMATE CONVERSIONS FROM SI UNITS | | | | |
|---|----------------------------|----------------------------|--------------------------------|-------------------|--|--------------------------------|-------------|----------------------------|---------------------|
| Symbol | When You Know | Multiply By | To Find | Symbol | Symbol | When You Know | Multiply By | To Find | Symbol |
| <u>LENGTH</u> | | | | | <u>LENGTH</u> | | | | |
| in | inches | 25.4 | millimeters | mm | mm | millimeters | 0.039 | inches | in |
| ft | feet | 0.305 | meters | m | m | meters | 3.28 | feet | ft |
| yd | yards | 0.914 | meters | m | m | meters | 1.09 | yards | yd |
| mi | miles | 1.61 | kilometers | km | km | kilometers | 0.621 | miles | mi |
| <u>AREA</u> | | | | | <u>AREA</u> | | | | |
| in ² | square inches | 645.2 | square millimeters | mm ² | mm ² | Square millimeters | 0.0016 | square inches | in ² |
| ft ² | square feet | 0.093 | square meters | m ² | m ² | Square meters | 10.764 | square feet | ft ² |
| yd ² | square yards | 0.836 | square meters | m ² | m ² | Square meters | 1.195 | square yards | yd ² |
| ac | acres | 0.405 | hectares | ha | ha | hectares | 2.47 | acres | ac |
| mi ² | square miles | 2.59 | square kilometers | km ² | km ² | Square kilometers | 0.386 | square miles | mi ² |
| <u>VOLUME</u> | | | | | <u>VOLUME</u> | | | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL | mL | milliliters | 0.034 | fluid ounces | fl oz |
| gal | gallons | 3.785 | liters | L | L | liters | 0.264 | gallons | gal |
| ft ³ | cubic feet | 0.028 | cubic meters | m ³ | m ³ | Cubic meters | 35.315 | cubic feet | ft ³ |
| yd ³ | cubic yards | 0.765 | cubic meters | m ³ | m ³ | Cubic meters | 1.308 | cubic yards | yd ³ |
| NOTE: Volumes greater than 1000L shall be shown in m ³ . | | | | | | | | | |
| <u>MASS</u> | | | | | <u>MASS</u> | | | | |
| oz | ounces | 28.35 | grams | g | g | grams | 0.035 | ounces | oz |
| lb | pounds | 0.454 | kilograms | kg | kg | kilograms | 2.205 | pounds | lb |
| T | short tons (2000lb) | 0.907 | megagrams (or "metric ton") | mg (or "t") | Mg | megagrams (or "metric ton") | 1.102 | short tons (2000lb) | T |
| <u>TEMPERATURE (exact)</u> | | | | | <u>TEMPERATURE (exact)</u> | | | | |
| °F | Fahrenheit temperature | 5(F-32)/9 or (F-32)/1.8 | Celsius temperature | °C | °C | Celsius temperature | 1.8C + 32 | Fahrenheit temperature | °F |
| <u>ILLUMINATION</u> | | | | | <u>ILLUMINATION</u> | | | | |
| fc | foot candles | 10.76 | lux | lx | lx | lux | 0.0929 | foot-candles | fc |
| fl | foot-Lamberts | 3.426 | candela/m ² | cd/m ² | cd/m ² | candela/m ² | 0.2919 | foot-Lamberts | fl |
| <u>FORCE AND PRESSURE OR STRESS</u> | | | | | <u>FORCE AND PRESSURE OR STRESS</u> | | | | |
| lbf | poundforce | 4.45 | newtons | N | N | newtons | 0.225 | poundforce | lbf |
| lbf/in ² | poundforce per square inch | 6.89 | kilopascals | kPa | kPa | kilopascals | 0.145 | poundforce per square inch | lbf/in ² |

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

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1. INTRODUCTION

1.1 BACKGROUND

1.1.1. NCHRP 350

A Federal Highway Administration (FHWA) guidance memorandum [1], dated July 27, 1997, mandated that all roadside and work zone devices used on the National Highway System (NHS) be crash tested to National Cooperative Highway Research Project (NCHRP) Report 350 [2] requirements. The FHWA categorized these devices into four categories, each having its own testing requirements and implementation date.

The difference between category testing depends on the type of device and the severity of velocity change from a possible vehicular impact with that device. Additionally there are 3 levels of the NCHRP Report 350 test. Each level is designed to represent a higher speed test impact.

The following is a brief description of the categories identified in Report 350:

Category I includes small and lightweight items, such as channelizing and delineating devices. Examples of Category I devices are cones and tubular markers. A self-certification is adequate for NCHRP 350 compliance for devices in this category.

Category II includes barricades, portable sign supports, vertical panels or cones with lights, and plastic drums. Category II devices qualify for reduced testing requirements.

Category III includes devices that might cause a significant velocity change upon vehicular impact. Devices classified in this category, such as barriers, crash attenuators, and fixed sign supports, are to be tested to the full requirements of NCHRP 350.

Category IV includes arrow displays or other trailer mounted devices, portable variable message signs, and portable traffic signals. These devices are not to be used if they are not tested to show that they are crashworthy, unless they are shielded or installed outside the clear zone.

1.1.2 FHWA Requirements

The FHWA is requiring that by October 1, 2002, all Temporary Concrete Barriers (TCBs) used on the National Highway System to be compliant with NCHRP Report 350. The exception is the TCB classified as an American Association of State Highway Officials (AASHTO) design, manufactured prior to October 1, 2000. Units built to the AASHTO TCB design can be used for the duration of their individual useful lives.

1.1.3 ADOT goal of providing a safe transportation environment

The Arizona Department of Transportation strives to always provide a safe transportation environment. It has the goal of providing Arizona's motoring public and visitors a quality and safe highway system. Safety and traffic control devices used by the department are therefore examined and evaluated closely.

1.2 PROJECT SCOPE

1.2.1 Implement an existing, approved system

The Jersey-shape system used by the Arizona Department of Transportation (ADOT) is not NCHRP 350 compliant (Appendix B), but has been accepted as an AASHTO design system.

In order for ADOT to comply with the FHWA requirements, a project panel was formed, representing affected sections of ADOT and with representation from the traffic control industry and the FHWA.

This panel determined that the most deliberate, expeditious, and cost effective method of approaching a solution was to review systems that had been tested and approved as compliant TCB.

1.2.2. Implement a similar system to ADOT's present system

A TCB system similar to that currently used by ADOT is desirable, since it would save on the cost of re-manufacturing concrete forms.

1.2.3 Meet FHWA compliance criteria

The selected system must meet NCHRP Report 350 criteria, as set forth by the FHWA memorandum requiring compliance by October 1, 2002.

2. EVALUATION AND SELECTION PROCESS

2.1 COMMITTEE

ADOT requested proposals from qualified researchers / investigators for an evaluation of its system and other agencies' designs that have passed NCHRP 350 testing that ADOT might be able to adopt, in order to comply with the federal mandate by the 2002 deadline. No qualified responses were received. Subsequently, the Technical Advisory Committee (TAC) / Evaluation Panel (EP) overseeing that research proposal agreed to investigate ADOT's options and provide findings and recommendations to ADOT management for the adoption of a qualified and compliant TCB system. The TAC/EP was comprised of members representing ADOT's Traffic Group, Planning Group, Research Group, Roadway Design, Construction, Construction Quality Control, and a District representative. Other ADOT groups were invited to participate, but declined. Additionally, the panel had members from the Arizona chapter of the American Traffic Safety Services Association (ATSSA), representing TCB manufacturers and traffic control contractors, and the FHWA.

2.2 SYSTEMS REVIEW

Currently, there are two common shapes of TCB: the Jersey shape and the F shape. The difference is the ground-up vertical dimension to the slope break point. The Jersey shape generally has a total of 13" for this dimension and the F shape generally has a total of 10".

Many states have tested their TCB systems, or modified versions of their systems, according to NCHRP 350 criteria and have obtained FHWA approval for their use on the National Highway System.

2.3 COMMITTEE EVALUATION

The TAC/EP agreed that ADOT should adopt a non-proprietary TCB system. In order to address the issue of differentiating between compliant systems and non-compliant systems after the October 1, 2002, deadline, the TAC/EP also agreed that a drop-dead date should be adopted. The TAC/EP industry representative suggested a date that spans 5 years beyond the adoption of a new system. This would allow the industry to recover its manufacturing cost of any system that was made up to that time. Additionally, the TAC/EP agreed that systems to be reviewed should be ones utilizing a pin and loop connection. Systems that do not use a pin and loop connection, such as those using slot or hook connections, were eliminated from this evaluation. Those systems are either proprietary or require additional care and time for installation and relocation. All wire loop systems have failed NCHRP 350 testing. National experts in NCHRP 350 testing, including FHWA test reviewers, have stated that, in their opinion, wire loop systems have a lesser chance of passing the crash test requirements.

2.4 CONSULTANT REVIEW

The TAC/EP was able to acquire the services of the Midwest Roadside Safety Facility (MwRSF), the University of Nebraska's research facility with some of the nation's foremost experts on NCHRP 350 crash testing, to review its evaluation. The Panel wants to emphasize that its work has withstood the scrutiny, and received the validation, of nationally-recognized crash testing experts. The Panel is therefore confident that it is providing the safest and best option to the citizens of Arizona.

3. EVALUATION

3.1 SYSTEMS EVALUATED

Based on remarks and recommendations from national experts, the TAC / EP decided that it would be counterproductive to test the ADOT TCB system. Significant modifications in the Arizona TCB system would be needed prior to its NCHRP 350 crash testing and that would still not guarantee adequate performance in the test. These design modifications and tests would most likely span beyond the mandated compliance date. Therefore, due to these recommendations and time constraints, the TAC/EP decided it would be best for ADOT to adopt a system already approved by the FHWA for use on the NHS.

Few TCB systems have passed NCHRP 350 testing. Of those that have, there are at least three proprietary (privately owned) systems that require a payment to the owner in order to use the design. Non-proprietary systems, however, which ADOT can use without a royalty payment, have been tested and been approved for Iowa, Georgia, California, Nevada, Virginia, California, Oregon, Idaho, and Ohio (assumed approval as of the date of the evaluation). The California, Nevada and Virginia systems require design considerations. The California and Nevada versions are K-shape. The Virginia design is not a pin and loop connection system. Georgia's system is a somewhat modified Jersey-shape. Iowa's system requires a bolt through the pin.

For the evaluation to cover the barrier shapes that are used in ADOT (F-shape for permanent installations and Jersey-shape for TCBs), the evaluation considered the Idaho, Ohio and Oregon designs. All three systems have non-proprietary designs, have passed NCHRP 350 testing, and utilize a pin and loop connection. The Oregon system is an F-shape system. The Idaho and Ohio systems are Jersey-shape systems.

Idaho has tested their 20-foot section system (Appendix B-3) and gotten approval from the FHWA for its use on the NHS. They have no Styrofoam pad requirement for the use of their system. They tested two connection mechanisms: one a bolt and the other a drop pin. The system can use a 25-inch long bolt and hex nut or a 26-inch long, 1.25-inch diameter rod that is not secured at the bottom. The deflection after the crash-test impact was 3.3 feet for the bolted connection system, and 3.6 feet for the pin connection.

Ohio has tested a 10-foot section (Appendix B-4) of their Jersey shape, and anticipates approval of a 12-foot section of the same design based on the performance in that test. The two systems are very similar except in length. The Ohio system uses a bolt connection and does not require a Styrofoam pad.

The third system is the Oregon F-shape design. The 12.5-foot long Oregon TCB system has been tested and approved in recent tests (Appendix B-2). Oregon tested 32-inch tall and 42-inch tall versions of their design. The taller barrier was tested to test levels 3 and 4 criteria with a bolt connection, to be used primarily in medians of all interstates and designated freight routes. The 32-inch (32" tall, 24" bottom width and 9.5" top width) design was tested to level 3 criteria with a pin connection. The approval letter issued by the FHWA (Appendix C-3) stated that both barriers exhibited the least amount of deflection and resulted in the most stable post impact vehicle trajectories of any free-standing precast barrier tested to date.

3.2 EVALUATION CRITERIA

Table One, on the following page, is an evaluation matrix that the TAC/EP developed to assist in ranking the systems under consideration. The Panel evaluated the systems and assigned points to each category. An average of the total score for each category is in its corresponding cell and the summation of these points is at the bottom of the matrix.

Arizona manufacturers and contractors of TCBs, via the ATSSA Panel representative, provided industry ranking, evaluation and comparison data for several of the matrix categories, such as ease of installation, cost and fabrication.

TABLE 1 - EVALUATION CRITERIA

| | Oregon F-Shape | Ohio Jersey-Shape. Tested 10' (Doesn't have approval yet, just tested, anticipates approval of 12' based on test) | Idaho Jersey-Shape 20' long |
|---|---|---|---|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 – 10) points | 7 | 6 | 7 |
| Fabrication - Form - materials (1 – 7) Points | 5 | 5 | 6 |
| Cost: (1 – 7) Points | 6 | 5 | 6 |
| Crash Testing (1 - 5) Points | 5 | 3 | 5 |
| More than one length (10', 12', 20') (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42") (1 - 5) Points | 5 | 4 | 3 |
| Inspection of Connection (1 - 5) Points | 5 | 4 | 5 |
| F Shape Jersey Shape | All compared as F Shape. See summary. | All compared as F Shape. See summary. | All compared as F Shape. See summary. |
| Drainage? (Yes / No) | | | |
| Ability to pin to pavement? (Yes / No) | | | |
| TOTAL | 38 | 33 | 35 |

Based on its evaluation, the TAC/EP ranked the Oregon F shape system as the most suitable design for ADOT use. The Oregon system performed best in crash testing and is equal or superior to the other systems it was compared to.

The Idaho system also rated well in this evaluation, but the Idaho TCB design is limited to a 20' section, and such long sections pose difficulty in certain installations such as on curves.

The scores of individual Panel members are in Appendix C.

The Panel unanimously recommended that ADOT adopt an F-shape barrier. In NCHRP 350 crash testing, the F-shape barrier has demonstrated a superior performance to that of Jersey-shape barrier.

This performance has been stated in several crash-testing review documents and in a paper by Mr. Charles F. McDevitt of the FHWA, entitled "Basics of Concrete Barriers." [3] Mr. McDevitt states that based on research and crash testing "*A parametric study (systematically varying the parameters) of various profile configurations that were labeled A through F showed that F performed distinctly better than the NJ-shape. The results of these computer simulations were confirmed by a series of full-scale crash tests. Configuration F became known as the F-shape.*"

4. RECOMMENDATIONS

The recommendations of the Technical Advisory Committee / Evaluation Panel are as follows:

4.1 SYSTEM

The TAC/EP recommends that ADOT adopt the non-proprietary, NCHRP 350 Test Level 3 approved, 12.5-foot long, 32-inch high Oregon TCB design as an ADOT TCB design. ADOT has already obtained approval from the FHWA for the manufacture of 20-foot sections of the Oregon TCB design.

4.2 IMPLEMENTATION DATE

The TAC/EP recommends that a drop-dead date of 5 years from the date of adoption be established for the use of the current TCB system. If the new system is adopted by ADOT on January 1, 2002, then barriers using the current design that were manufactured before October 2000, can be used for up to 5 years from that adoption date, based on their condition. That is, by January 1, 2007, all TCBs installed on ADOT projects shall be of the new design, with no exceptions.

This approach was part of ADOT's agreement with FHWA for the October 2000 AASHTO TCB design acceptance. This drop-dead date has been established in conjunction with the industry, FHWA and concerned sections of ADOT.

4.3 INCENTIVE

The panel discussed recommending incentive pay to TCB contractors to expedite the implementation of the new design. After considering the consultant review and panel discussion, it was agreed that, although it is a desirable approach, it might be best recommended by the industry or ADOT Construction Group directly to management.

4.4 CONSULTANT REVIEW

Dr. Dean Sicking, Ph.D., P.E., director of MwRSF, in his review of the TAC/EP summary report (Appendix D), agreed with the panel's finding, with two recommendations. The first was to add a fracture-resistant steel specification, which requires steel that will not fracture in cold areas (temperatures of freezing and below). The second was that the panel not recommend incentive pay since there is no cost or added benefit from an expedited implementation.

5. IMPLEMENTATION

5.1 PLAN

The Oregon TCB system was selected by the panel for adoption by ADOT. The Oregon standard drawings have been converted into ADOT standard drawings (Appendix B-1), with notations specifying fracture-resistant steel, and implementation dates. These drawings will be signed and approved for distribution by affected group managers, thus becoming the new ADOT standard. On the drawings, the implementation date will serve as a reminder and support to contract documents that outline the drop-dead date requirements.

5.2 APPROVALS

The adopted system and implementation dates, including the five-year span from date of adoption for use of ADOT's AASHTO design TCBs, have been discussed with ADOT management and have been accepted. A signed standard drawing will be distributed and posted replacing the old ADOT TCB design with the new Oregon-based design.

5.3 INDUSTRY PARTNERING

Based on this evaluation, the industry representatives stated at a partnering meeting that they will most likely begin manufacturing the new design as soon as they receive signed copies of the standard drawings. These drawings will serve as notification to ADOT designers, consultants and contractors of the adoption of the new system.

APPENDIX A: LIST OF PANEL EVALUATION TABLES

The following are evaluation tables as scored by panel members.

Blank Form Used for the Evaluation:

| | Oregon F Shape | Ohio Jersey Shape. Tested 10' (Doesn't have approval yet, just tested, anticipates approval of 12' based on test) | Idaho Jersey Shape 20' long |
|---|---|--|---|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | | | |
| Fabrication - Form - materials (1 - 7) Points | | | |
| Cost: (1 - 7) Points | | | |
| Crash Testing (1- 5) points | | | |
| More than one length (10', 12', 20')? (1 - 5) Points | | | |
| More than one height (32", 42")? (1 - 5) Points | | | |
| Inspection of Connection? (1 - 5) Points | | | |
| F Shape / Jersey Shape | All compared as F Shape. See summary. | All compared as F Shape. See summary. | All compared as F Shape. See summary. |
| Drainage? (Yes / No) | See summary | See summary | See summary |
| Ability to pin to pavement? (Yes / No) | See summary | See summary | See summary |
| TOTAL | | | |

Panel Member A:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|---|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 5 | 3 | 7 |
| Fabrication - Form - materials (1 - 7) Points | 5 | 6 | 7 |
| Cost: (1 - 7) Points | 5 | 6 | 7 |
| Crash Testing (1- 5) points | 5 | 5 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 6 | 6 | 2 |
| More than one height (32", 42")? (1 - 5) Points | 6 | 6 | 2 |
| Inspection of Connection? (1 - 5) Points | 5 | 4 | 5 |
| TOTAL | 37 | 36 | 35 |

Panel Member B:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 5 | 3 | 7 |
| Fabrication - Form - materials (1 - 7) Points | 5 | 6 | 7 |
| Cost: (1 - 7) Points | 6 | 5 | 7 |
| Crash Testing (1- 5) points | 5 | 3 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 4 | 4 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 5 | 2 |
| Inspection of Connection? (1 - 5) Points | 5 | 3 | 5 |
| TOTAL | 36 | 29 | 37 |

Panel Member C:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 8 | 9 | 6 |
| Fabrication - Form - materials (1 - 7) Points | 6 | 6 | 6 |
| Cost: (1 - 7) Points | 6 | 4 | 6 |
| Crash Testing (1- 5) points | 5 | 3 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 4 | 4 |
| Inspection of Connection? (1 - 5) Points | 5 | 4 | 5 |
| TOTAL | 40 | 35 | 35 |

Panel Member D:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 8 | 9 | 6 |
| Fabrication - Form - materials (1 - 7) Points | 6 | 6 | 6 |
| Cost: (1 - 7) Points | 6 | 4 | 6 |
| Crash Testing (1- 5) points | 5 | 3 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 4 | 4 |
| Inspection of Connection? (1 - 5) Points | 5 | 4 | 5 |
| TOTAL | 40 | 35 | 35 |

Panel Member E:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 8 | 5 | 8 |
| Fabrication - Form - materials (1 - 7) Points | 5 | 6 | 7 |
| Cost: (1 - 7) Points | 6 | 5 | 4 |
| Crash Testing (1- 5) points | 5 | 3 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 3 | 3 |
| Inspection of Connection? (1 - 5) Points | 5 | 4 | 3 |
| TOTAL | 39 | 31 | 33 |

Panel Member F:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 5 | 5 | 5 |
| Fabrication - Form - materials (1 - 7) Points | 4 | 5 | 5 |
| Cost: (1 - 7) Points | 6 | 6 | 6 |
| Crash Testing (1- 5) points | 5 | 2 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 4 | 4 |
| Inspection of Connection? (1 - 5) Points | 5 | 3 | 4 |
| TOTAL | 35 | 30 | 32 |

Panel Member G:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 9 | 7 | 10 |
| Fabrication - Form - materials (1 - 7) Points | 5 | 6 | 7 |
| Cost: (1 - 7) Points | 7 | 7 | 7 |
| Crash Testing (1- 5) points | 5 | 1 | 3 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 3 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 5 | 5 |
| Inspection of Connection? (1 - 5) Points | 5 | 3 | 5 |
| TOTAL | 41 | 32 | 40 |

Panel Member H:

| | Oregon F Shape | Ohio Jersey Shape. (Not approved yet, anticipates approval based on recent test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 7 | 5 | 6 |
| Fabrication - Form - materials (1 - 7) Points | 6 | 6 | 7 |
| Cost: (1 - 7) Points | 6 | 5 | 6 |
| Crash Testing (1- 5) points | 5 | 4 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 4 | 3 |
| Inspection of Connection? (1 - 5) Points | 5 | 3 | 5 |
| TOTAL | 39 | 32 | 35 |

Total Average:

| | Oregon F Shape | Ohio - Jersey Shape. Tested 10' (Doesn't have approval yet, just tested, anticipates approval of 12' based on test) | Idaho Jersey Shape 20' long |
|--|--------------------------|--|--|
| Ease of Installation Turn System around. Transporting. Handling. Bolt and Pin or Cotter Pin. Tolerance between sections. Repair. (1 - 10) points | 7 | 6 | 7 |
| Fabrication - Form - materials (1 - 7) Points | 5 | 6 | 6 |
| Cost: (1 - 7) Points | 6 | 5 | 6 |
| Crash Testing (1 - 5) Points | 5 | 3 | 5 |
| More than one length (10', 12', 20')? (1 - 5) Points | 5 | 5 | 3 |
| More than one height (32", 42")? (1 - 5) Points | 5 | 4 | 3 |
| Inspection of Connection? (1 - 5) Points | 5 | 4 | 5 |
| TOTAL | 38 | 33 | 35 |

APPENDIX B: SYSTEM DRAWINGS

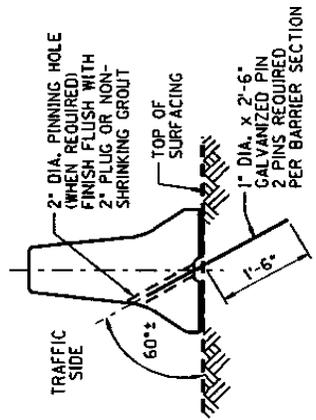
B-1: Arizona DOT Approved NCHRP-350 Compliant Design (3 Sheets)

B-2: Oregon DOT Compliant Design Drawings (2 Sheets)

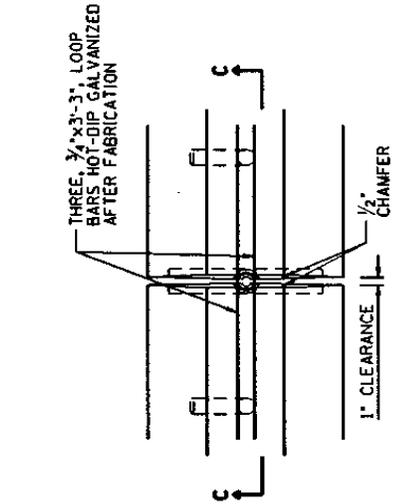
B-3: Idaho DOT Compliant Design Drawings (2 Sheets)

B-4: Ohio DOT Compliant Design Drawings (2 Sheets)

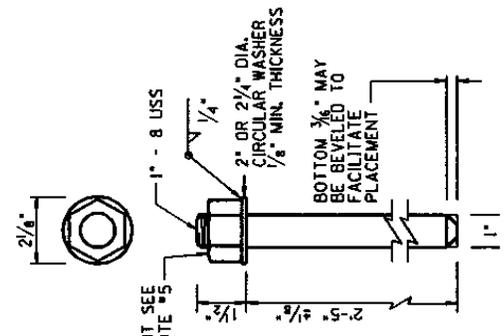
| | | |
|-----|-------------|------|
| NO. | DESCRIPTION | DATE |
| 1 | SCALE | 2/02 |
| 2 | | |
| 3 | | |
| 4 | | |



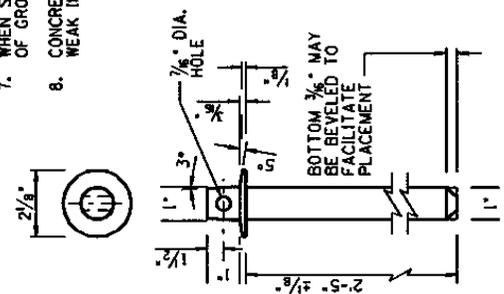
PINNING CONCRETE BARRIER TO ROADWAY DETAIL
(USE WHEN REQUIRED BY PLANS OR AS DIRECTED)



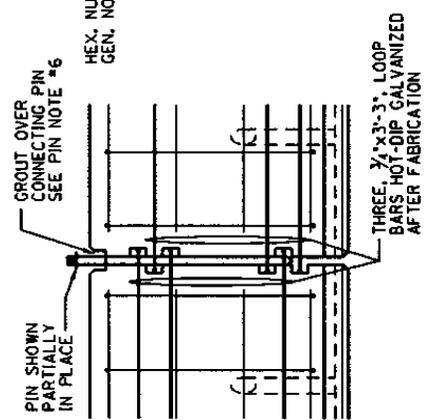
PLAN
FOR DETAILS NOT SHOWN SEE END VIEWS 'A-A' & 'B-B' SHEET 1 OF 3



PIN DETAIL
1" PIN GALVANIZE AFTER FABRICATION



ALTERNATE PIN DETAIL
1" PIN GALVANIZE AFTER FABRICATION



SECTION C-C
FOR DETAILS NOT SHOWN SEE END VIEWS 'A-A' & 'B-B' SHEET 1 OF 3

GENERAL NOTES:

1. ALL TEMPORARY CONCRETE BARRIERS INSTALLED ON ADOT PROJECTS AFTER JANUARY 1, 2007, SHALL BE IN ACCORDANCE WITH SHEETS 1 & 2 OF THIS STANDARD DRAWING (NCHRP 350 APPROVED DESIGN).
2. TEMPORARY CONCRETE BARRIER IS TO BE PRECAST CONCRETE MEDIAN BARRIER WITH PIN AND LOOP ASSEMBLY.
3. ALL METAL REINFORCING SHALL BE 2 INCHES CLEAR OF NEAREST FACE OF CONCRETE UNLESS OTHERWISE SHOWN.
4. INSTALL TYPE BM-1 OR BM-2 BARRIER DELINEATORS AT 25 FT. SPACING. SEE STD. DWG. M-32 & M-33.
5. NORMAL USE OF PRECAST BARRIER UNITS IS RESTRICTED TO CURVATURES WITH RADIUS GREATER THAN 771 FEET.
6. MAXIMUM CHORD LENGTH FOR CURVES WITH A 1427 FT. RADIUS OR LESS, SHALL BE 12'-6" MAXIMUM CHORD LENGTH FOR CURVES WITH RADIUS EXCEEDING 1427 FEET, SHALL BE 25 FEET.
7. WHEN SCUPPERS ARE NOT REQUIRED, PLUG THEM WITH 2 INCHES OF GROUT, MINIMUM.
8. CONCRETE GROUTING OF SCUPPERS, SHALL BE NON-SHRINKING, WEAK IN STRENGTH AND OF THICK CONSISTENCY.

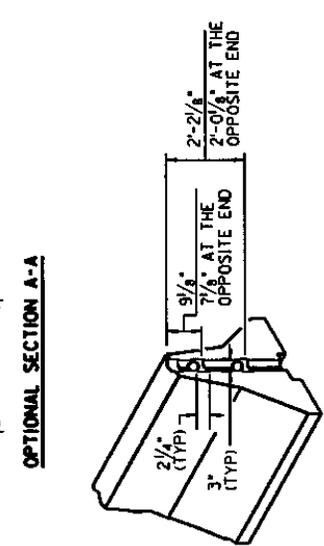
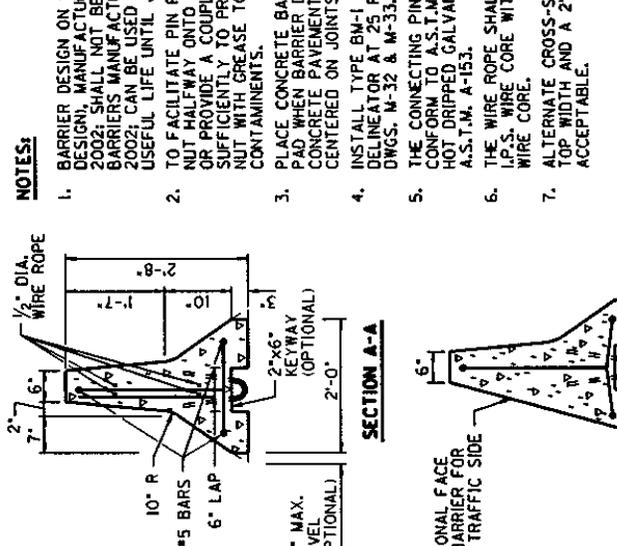
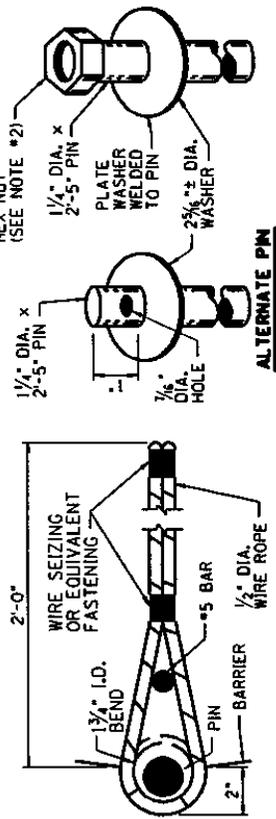
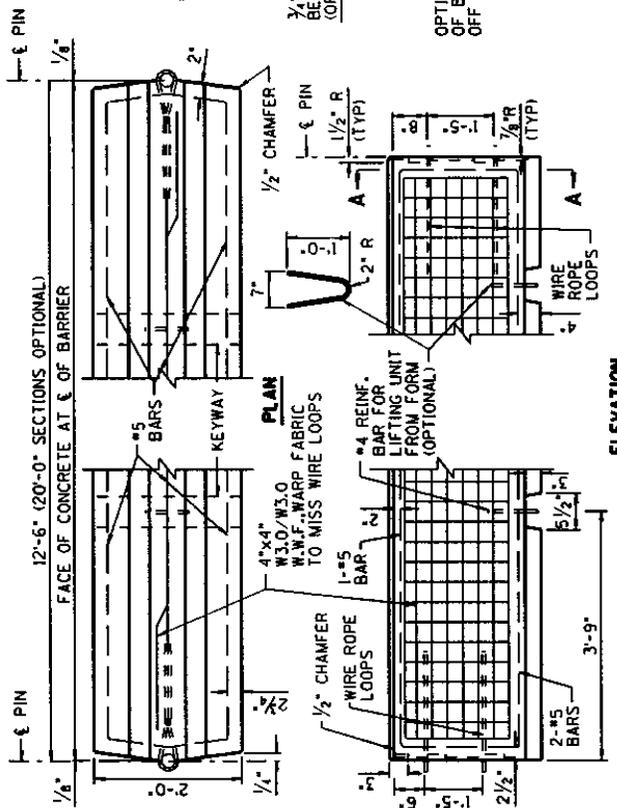
PIN NOTES:

1. WASHER SHALL BE FORGED AS INTEGRAL PART OF THE PIN OR SHALL BE WELDED AS SHOWN.
2. PIN SHALL BE GALVANIZED AFTER FABRICATION ACCORDING TO ASTM A153.
3. PINS THAT CONFORM TO CRITICAL DIMENSIONS, (PIN LENGTH & DIA. WASHER DIA. & THICKNESS) ARE ACCEPTABLE IF AN APPROVED TOP CONFIGURATION FOR LIFTING THE PIN IS PROVIDED.
4. PINS SHALL CONFORM TO ASTM A449.
5. TO FACILITATE PIN REMOVAL: THREAD HEX. NUT HALF WAY ONTO THE PIN AND TACK WELD OR PROVIDE A COUPLING NUT. TIGHTEN SUFFICIENTLY TO PREVENT LOOSENING. FILL NUT WITH GREASE TO EXCLUDE ICE OR OTHER CONTAMINANTS.
6. CONCRETE GROUTING OVER PINS AND PINNING HOLES, SHALL BE NON-SHRINKING, WEAK IN STRENGTH AND OF THICK CONSISTENCY.

| | |
|--|---------------------------|
| ADOT ARIZONA DEPARTMENT OF TRANSPORTATION INTERMODAL TRANSPORTATION DIVISION STANDARD DRAWINGS | SHEET NO. 2/02 |
| | PROJECT NO. C-3 |

SHEET 2 OF 3
NOT TO SCALE

| | | |
|-----|----------|------|
| NO. | REVISION | DATE |
| 1 | ISSUE | 2/02 |
| 2 | REVISED | |
| 3 | | |
| 4 | | |



- NOTES:**
- BARRIER DESIGN ON SHEET 3 OF 3 (ADOT DESIGN), MANUFACTURED AFTER OCTOBER 1, 2002; SHALL NOT BE USED ON ADOT PROJECTS. BARRIERS MANUFACTURED PRIOR TO OCTOBER 1, 2002; CAN BE USED FOR THE DURATION OF ITS USEFUL LIFE UNTIL JANUARY 1, 2007.
 - TO FACILITATE PIN REMOVAL, THREAD HEX. NUT HALF-WAY ONTO THE PIN AND TACK WELD, OR PROVIDE A COUPLING NUT, TIGHTENED SUFFICIENTLY TO PREVENT LOOSENING. FILL NUT WITH GREASE TO EXCLUDE ICE OR OTHER CONTAMINANTS.
 - PLACE CONCRETE BARRIER ON 1" STYROFOAM PAD WHEN BARRIER IS PLACED ON A.C. AND CONCRETE PAVEMENT. PAD SHALL BE 2'-0" x 1'-0" CENTERED ON JOINTS.
 - INSTALL TYPE BM-1 OR BM-2 BARRIER DELINEATOR AT 25 FT. SPACING. SEE STD. DWGS. M-32 & M-33.
 - THE CONNECTING PIN, WASHER AND NUT SHALL CONFORM TO A.S.T.M. A-36/A36M STEEL AND HOT DRIPPED GALVANIZED ACCORDING TO A.S.T.M. A-153.
 - THE WIRE ROPE SHALL BE 1/2" DIA. - 6x19 I.P.S. WIRE CORE WITH INDEPENDENTLY WOUND WIRE CORE.
 - ALTERNATE CROSS-SECTION DESIGN WITH A 8" TOP WIDTH AND A 2'-2" BOTTOM WIDTH IS ACCEPTABLE.

PRECAST NOTES:
CONCRETE 28 DAY DESIGN STRENGTH OF $f'_c = 30$ MPa.
WELDED WIRE FABRIC SHALL CONFORM TO THE REQUIREMENTS OF AASHTO M55.

WIRE ROPE DETAIL
(SEE NOTE #6)

END SECTION VIEW

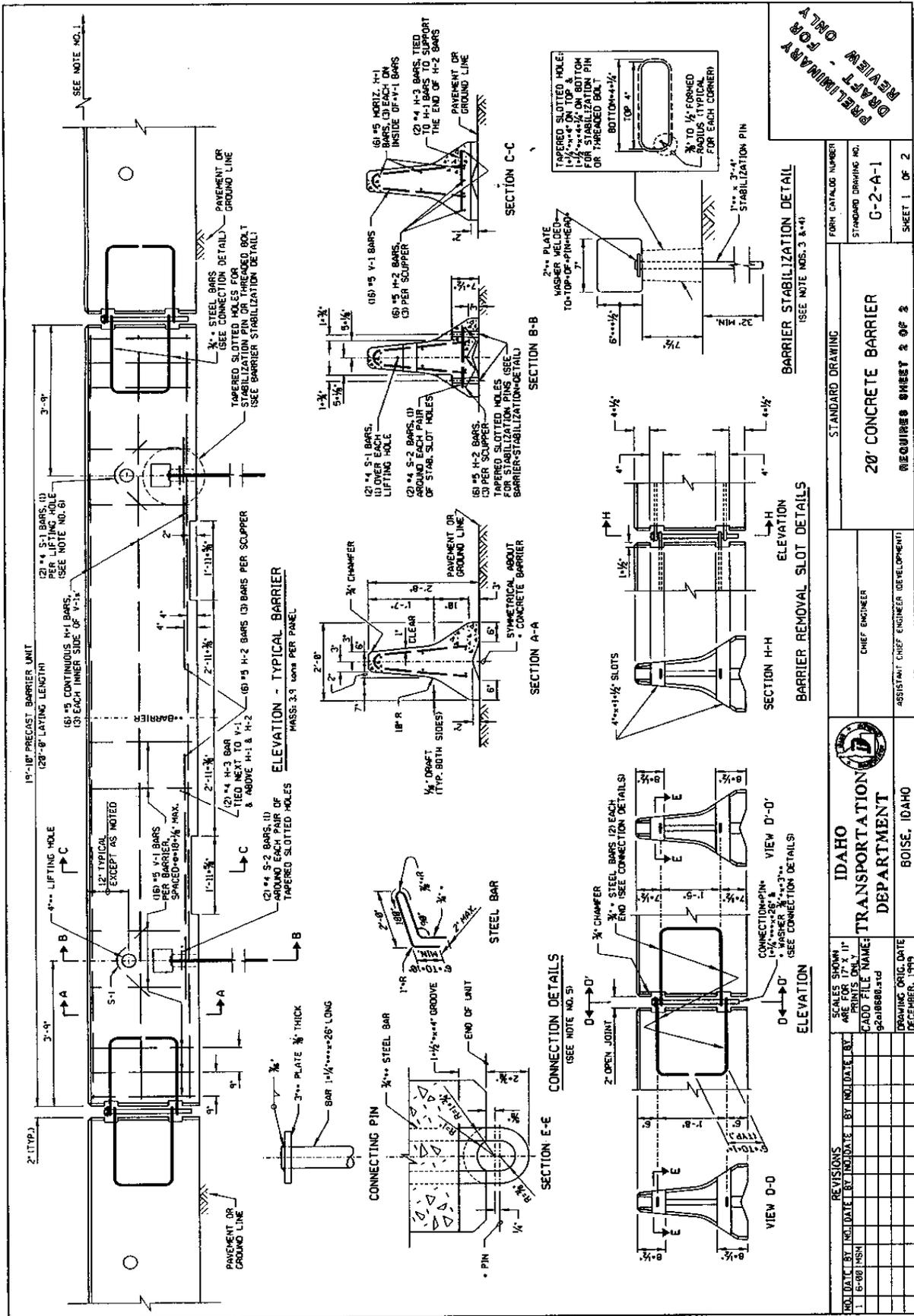
SHEET 3 OF 3
NOT TO SCALE

STA NO
ENDL/STATION

ARIZONA DEPARTMENT OF TRANSPORTATION
INTERMODAL TRANSPORTATION DIVISION
STANDARD DRAWINGS

PROJECT NO. 2/02

PRECAST CONCRETE BARRIER
PIN AND LOOP ASSEMBLY
ADOT DESIGN C-3



PRELIMINARY
 DRAWING - FOR
 REVIEW ONLY

STANDARD DRAWING NO.
C-2-A-1
 SHEET 1 OF 2

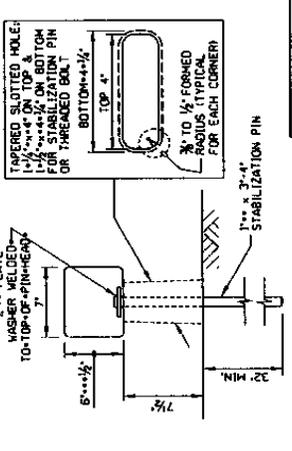
STANDARD DRAWING
20' CONCRETE BARRIER
 REQUIRES SHEET 2 OF 2

CHIEF ENGINEER
 ASSISTANT CHIEF ENGINEER DEVELOPMENT

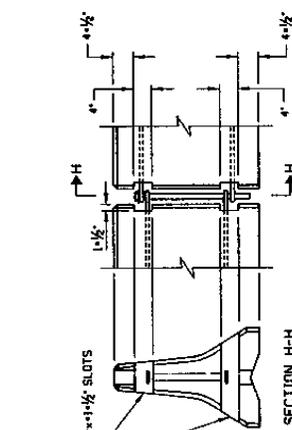
IDAHO
TRANSPORTATION
DEPARTMENT
 BOISE, IDAHO

| NO. | DATE | BY | REVISIONS |
|-----|----------|-----|---|
| 1 | 10-08-10 | NSM | SCALE SHOWN ARE FOR 17" X 11" PRINTS ONLY |
| | | | CADD FILE NAME: 92a16888.rtd |
| | | | DRAWING ORIG. DATE: DECEMBER, 1995 |

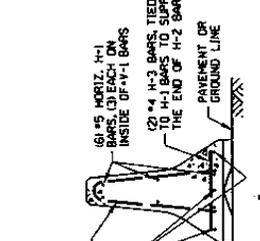
BARRIER STABILIZATION DETAIL
(SEE NOTE NOS. 3 & 4)



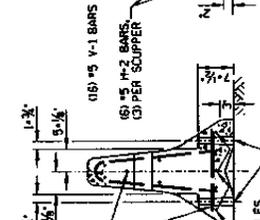
BARRIER REMOVAL SLOT DETAILS
ELEVATION



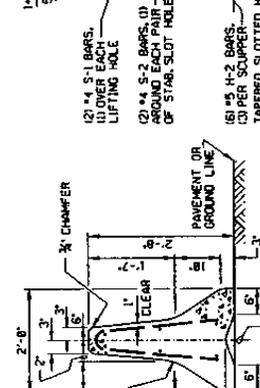
SECTION C-C



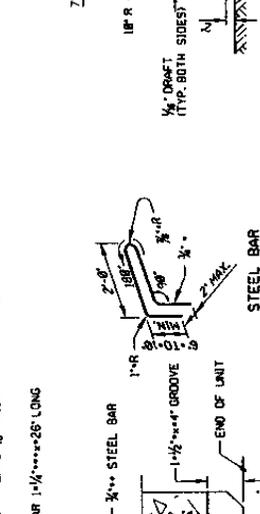
SECTION B-B



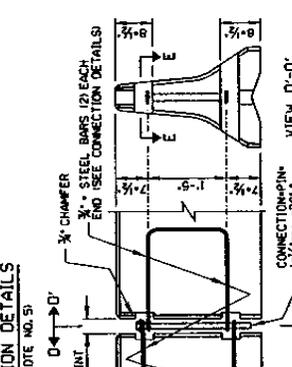
SECTION A-A



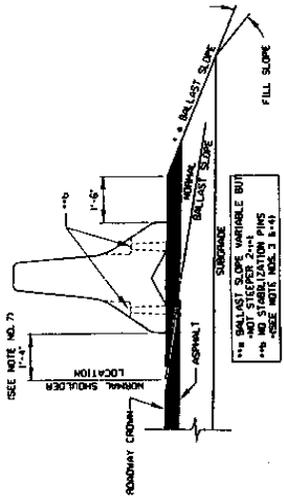
CONNECTION DETAILS
(SEE NOTE NO. 5)



ELEVATION



PRELIMINARY
 DRAWING - FOR
 REVIEW ONLY



STANDARD INSTALLATION
SEE NOTE NO. 7)

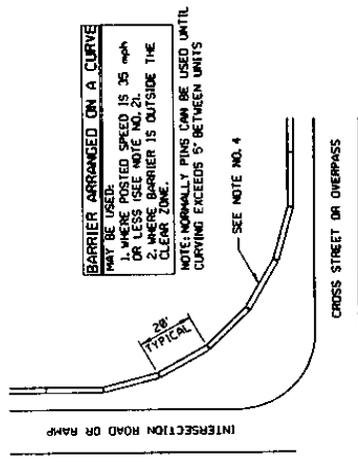
TABLE OF MAXIMUM TAPERS FOR CONCRETE BARRIER

| DESIGN SPEED (mph) | TAPER |
|--------------------|---------|
| 70 | 20° ± 1 |
| 60 | 17° ± 1 |
| 50 | 14° ± 1 |
| 45 | 13° ± 1 |
| 40 | 11° ± 1 |
| 35 | 10° ± 1 |

NOTES

- FOR END TREATMENT LAYOUT, CRASH CUSHIONS, AND WHERE NEEDED SEE PROJECT PLANS OR SPECIAL PROVISIONS.
- FOR SPEEDS GREATER THAN OR EQUAL TO 35 MPH BARRIERS MUST BE PINNED TOGETHER AND CAN NOT EXCEED THE TABLE OF MAXIMUM TAPERS.
- THE CONCRETE BARRIER STANDARD INSTALLATION DESIGN ALLOWS FOR 3'-3" OF OUTWARD LATERAL MOVEMENT IF THE BARRIER IS STRUCK. BARRIER INSTALLATIONS THAT REQUIRE LESS THAN THE 3'-3" OF OUTWARD LATERAL MOVEMENT SHOULD HAVE STABILIZATION PINS.
- ATTACH UNITS TO ROADWAY SURFACE WITH STABILIZATION PINS AND TO DECK SLABS USING BOLTS WHEN REQUIRED.
- ASTM A-36 STEEL SHALL BE USED FOR THE CONNECTION PIN. CONNECTION LOOPS, AND STABILIZATION PINS SHALL BE PINNED WITH CONNECTION PIN IF THE ON PIECE PIN MEETS ASTM A-36 REQUIREMENTS.
- A 4" WHITE PVC SLEEVE MAY BE USED TO FORM THE LIFTING HOLE AND IF USED THE SLEEVE IS TO BE LEFT IN PLACE.
- THIS DISTANCE IS 1'-4" FOR STRUCTURAL DIMENSIONING.
- NOT TO SCALE.

BARRIER ARRANGED ON A CURVE
 MAY BE USED:
 1. WHERE POSTED SPEED IS 35 mph
 2. WHERE POSTED SPEED IS 20 mph
 3. WHERE BARRIER IS OUTSIDE THE CLEAR ZONE.
 NOTE: NORMALLY PINS CAN BE USED UNTIL CURVING EXCEEDS 5° BETWEEN UNITS
 SEE NOTE NO. 4



CURVED LAYOUT

METAL REINFORCEMENT TABLE

| MARK | LOCATION | BAR SIZE | NO. BARS | SKETCH |
|------|---|----------|----------|--|
| H-1 | HORIZONTAL IN BARRIER TIED INSIDE V-1 BARS | #5 | (6) | 19'-3" |
| H-2 | SCUPPERS LONG, CENTERED ABOVE & TRANSVERSELY | #5 | (6) | 6'-6" |
| H-3 | SCUPPERS SHORT, TIED TO SUPPORT | #4 | (2) | 1'-6" |
| S-1 | HORIZ. IN TOP OF WING WALL & IN FLOOR BACK WALL | #4 | (2) | LIFTING HOLE |
| S-2 | HORIZ. AROUND SLOTS BETWEEN V-1'S & SCUPPERS | #4 | (2) | 5'-1" BAR, 1/4" DIA. 1 1/2" W/ 1'-8" OVERLAP |
| V-1 | VERTICAL IN FRONT OF EACH SCUPPER | #5 | (16) | TOTAL LENGTH 4'-4" 2'-11 3/4" 4'-3" |

STANDARD DRAWING
20' CONCRETE BARRIER
 REQUIRES SHEET 1 OF 2

FORM CATALOG NUMBER
 STANDARD DRAWING NO.
C-2-A-1
 SHEET 2 OF 2

ASSISTANT CHIEF ENGINEER (DEVELOPMENT)
 CHIEF ENGINEER

IDAHO
TRANSPORTATION
DEPARTMENT
 BOISE, IDAHO

SCALE FOR 17 1/2" X 11" PRINTS ONLY
 CAD FILE NAME:
 02-016608.r10

REVISIONS
 NO. DATE BY NO. DATE BY NO. DATE BY
 1 5-90 HSH

DRAWING ORIG. DATE
 DECEMBER, 1999

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|

THIS DRAWING REPLACES RM-4-2M DATED 10-21-97.

STANDARD ROADWAY CONSTRUCTION DRAWING
 PORTABLE CONCRETE BARRIER
 32" (813 mm)

ROADWAY ENGINEERING SERVICES
 ALL metric dimensions in millimeters unless otherwise noted.
 M. EVANS
 O. FROCK

CHD DEPARTMENT OF TRANSPORTATION
 DATE: 05-27-01

MEMBER RM-4-2

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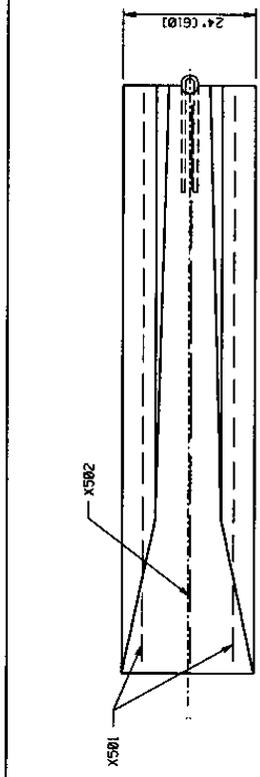
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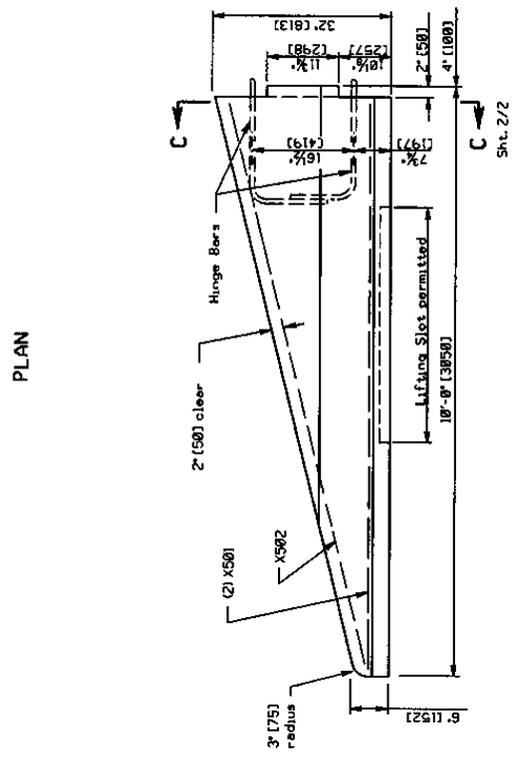


PLAN

PLAN

PLAN

PLAN



ELEVATION

ELEVATION

ELEVATION

ELEVATION

PORTABLE CONCRETE BARRIER (PCB) PCB, as shown, shall not be used on bridge deck edges. PCB, Bridge Mounted, shall be used at such locations in accordance with Structural Engineering's Standard Drawing PCB-9 [PCB-91M].

CONNECTING HARDWARE Bolts, washers and hex nuts shall be galvanized in lieu of the pin and loop connections detailed on this Standard Construction Drawing. Barrier sections with "J-J" Hooks and connections may be utilized.

Non barrier sections with pin and loop connections on one end and "J-J" Hooks on the other shall be used to connect runs of "J-J" Hooks barrier to other permitted barrier sections. The transition sections shall be the same as the barrier runs being connected. "J-J" Hooks is a trademark of East-Set Industries, P.O. Box 300, Midland, VA 22726, (540) 439-8911 or (800) 547-4045.

PORTABLE CONCRETE BARRIER (PCB) PCB, as shown, shall not be used on bridge deck edges. PCB, Bridge Mounted, shall be used at such locations in accordance with Structural Engineering's Standard Drawing PCB-9 [PCB-91M].

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Non barrier sections with pin and loop connections on one end and "J-J" Hooks on the other shall be used to connect runs of "J-J" Hooks barrier to other permitted barrier sections. The transition sections shall be the same as the barrier runs being connected. "J-J" Hooks is a trademark of East-Set Industries, P.O. Box 300, Midland, VA 22726, (540) 439-8911 or (800) 547-4045.

HINGE AND REINFORCING BARS: The 3/4" (19) hinge bars, #3 (E20M), and #5 (16M) reinforcing bars shall meet the requirements of CMS 585.

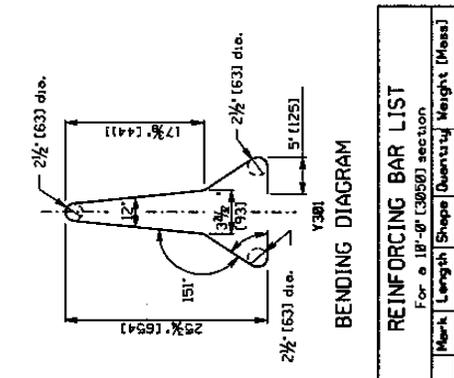
HANDLING DEVICES: Such devices may be used in lieu of the lifting slot for moving the barrier. They may be of any design sufficient to handle the weight of the section being lifted. No handling devices shall protrude from the surface of the barrier when in place.

MARKING: All barrier segments shall be marked as shown, where XX indicates the year cast. These markings shall be permanently impressed in the barrier using a minimum of 2" (50) high lettering. Each segment shall have, on its top, a unique identification as to its manufacturer and company on the barrier, the day and month that the barrier was manufactured.

See CMS 622 for additional information.

REFLECTORIZATION: Barrier reflectors shall be installed in accordance with Traffic Engineering's Standard Drawing TR-95.85 when specified in the plans.

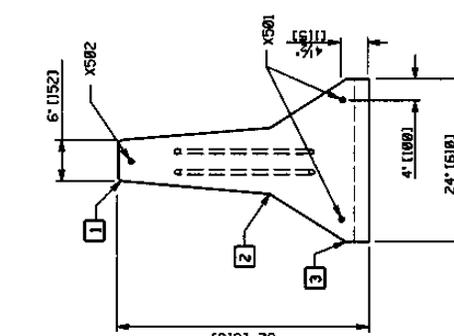
NOTES



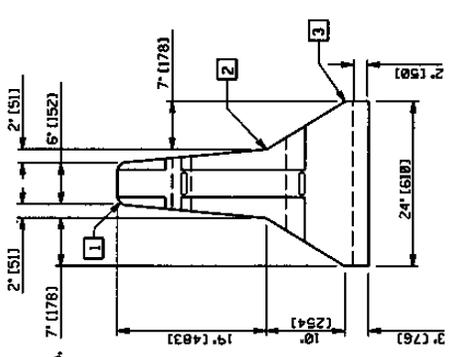
REINFORCING BAR LIST
 For a 18"-gr (3950) section.

| Mark | Length | Shape | Quantity | Weight [Mass] |
|------------------------------|--------|-------|----------|--------------------|
| Y301 | 5'-5" | Bent | 11 | 2.0 lbs (0.9 kg) |
| X501 | 9'-6" | Str. | 5 | 9.9 lbs (4.5 kg) |
| Total (for information only) | | | | 71.4 lbs (32.4 kg) |
| X501 | 9'-6" | Str. | 2 | 9.9 lbs (4.5 kg) |
| X502 | 9'-8" | Str. | 1 | 10.1 lbs (4.6 kg) |
| Total (for information only) | | | | 29.9 lbs (13.5 kg) |

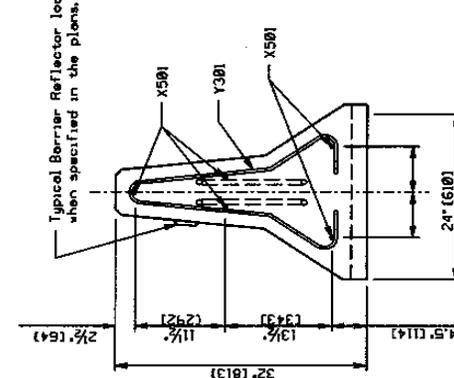
- LEGEND**
- 1 1" (25) radius or 3/4" (19) chamfer, all top and end corners.
 - 2 Permissible 10" (250) radius.
 - 3 Permissible 1" (25) radius.



SECTION C-C
 See Sheet 1 of 2.



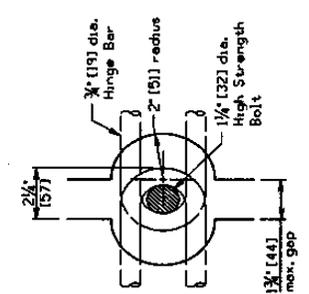
VIEW B-B
 See Sheet 1 of 2.



SECTION A-A
 See Sheet 1 of 2.

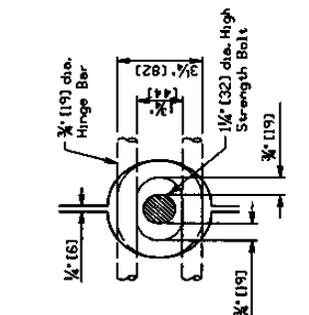
Vertical edges on Keyway and Drainage Slots may be battered. Depth 2 1/4" (59.5).

Typical Barrier Reflector location, when specified in the plans.



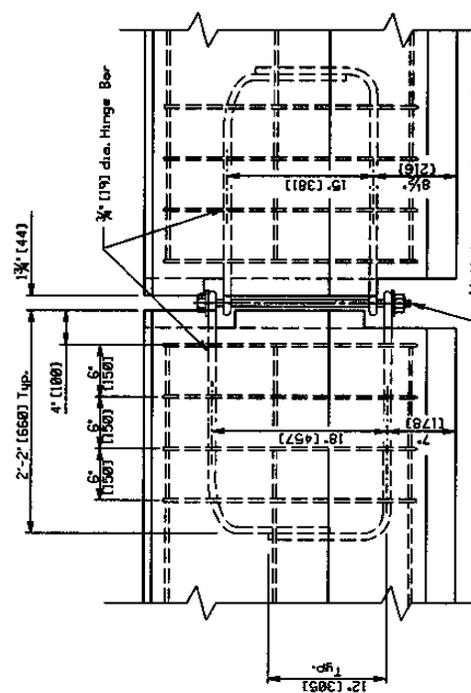
OPEN JOINT

Barrier joints shall be fully open before the Nut is tightened onto Bolt.



CLOSED JOINT

Barriers shall initially be placed close together so that Bolts can be easily inserted through Hinge Bar loop.



DETAIL AT HINGED CONNECTION

JOINT CONNECTION DETAILS

APPENDIX C: APPROVAL LETTERS

- C-1: FHWA Approval Letter - 12/28/00 - Arizona AASHTO Compliant Design (2 Pages)**
- C-2: FHWA Approval Letter - 01/15/02 - 20' Oregon-Based Arizona Design (1 Page)**
- C-3: FHWA Approval Letter - 08/17/00 - Oregon Compliant Design (2 Pages)**
- C-4: FHWA Approval Letter - 07/17/00 - Idaho Compliant Design (2 Pages)**



U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
ARIZONA DIVISION
234 N. Central Avenue, Suite 330
Phoenix, AZ. 85004
December 28, 2000

IN REPLY REFER TO
HA-AZ
(804)

Mr. Muhannad M. A. Zubi
Traffic Group (061R)
Arizona Department of Transportation
Phoenix, Arizona 85007

Dear Mr. Zubi

We received your memorandum, of July 24, 2000, requesting approval to use Temporary Concrete Barrier (TCB), per ADOT Standard Drawing 4-C-2.01, for the duration of the service life of the barrier manufactured before October 1, 2000. If approved ADOT agrees to change the pin diameter to use a 1 1/4 inch pin that is 29-inches long.

At our meeting on August 24, 2000 we discussed the use of TCB in relation to the requirements for crashworthy work zone devices in accordance with guidelines for crash testing in NCHRP 350. The following information summarizes the meeting discussions:

- At the states discretion, TCB manufactured, to the current ADOT standard (4-C-2.01) with the 1-1/4 inch by 29-inch pin, prior to October 1, 2000 may be used for the remainder of its useful service life. Also TCB manufactured to the above standard prior to October 2, 2002 may also be used until the October 1, 2002 date.

Some further guidance needs to be identified based on this agreement;

- The term "useful service life" needs to be fully understood and the following questions need to be answered;

What system will be established to identify barriers that were constructed prior to October 1, 2000?

What construction monitoring will be needed to assure which barrier is in use and what connections are appropriate?

What criteria is either in place or will need to be developed to verify when the barrier service life is over?

This agreement allows time (before October 1, 2002) to develop a policy on what design of TCB will be allowed in the future and what implementation date will be adopted for any new policy. Two options discussed included:

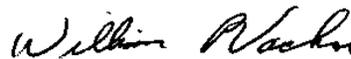
- 1) ADOT will develop a new standard drawing that meets NCHRP-350 requirements and select a date (in the near future) where all new projects will require that TCB meet the new standard.
- 2) ADOT will have their current TCB evaluated and crash tested. If the TCB passes crash testing then the current barrier design may continue to be used (with potential modifications based on the crash testing).

Based on the meeting ADOT will determine which of the two options listed above they plan to follow.

Since our meeting, FHWA has issued a memorandum dated September 13, 2000, titled "**INFORMATION: Crashworthy Work Zone Devices as of October 1, 2000,**" copy enclosed. As indicated in the memorandum, page 5, under **CATEGORY III DEVICES**, "For all NHS projects advertised after October 1, 2002, newly-purchased concrete barriers must have been successfully crash tested to meet NCHRP Report 350 evaluation criteria."

If you wish to discuss this further please give Jennifer Brown (602-379-3923) or Bill Vachon (602-379-3920) a call.

Sincerely,



For Robert E. Hollis
Division Administrator

Enclosure

cc:
R. Williams (ADOT 172A) w/enc.
M. Manthey (ADOT 204E) w/enc.
T. Otterness (ADOT 615E) w/enc.
P. Hurst (ADOT 134A) w/enc.



U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
ARIZONA DIVISION
234 N. Central Ave. Suite 330
Phoenix, Arizona 85004
January 15, 2002

REC'D JAN 18 2002

IN REPLY REFER TO

HPR-AZ

(807)

20' Oregon F-Shape TCB

Mr. Al Zubi
Traffic Engineering
Arizona Department of Transportation, (063R)
Phoenix, Arizona 85007

Dear Mr. Zubi:

Your letter of January 8, 2002 requested FHWA's approval of the 20-foot section of Oregon's Temporary Concrete Barrier (TCB) design for use on the National Highway System.

According to the guidance we received from Headquarters, the Division Offices have the authority to accept longer sections of NCHRP 350 Crash Tested TCB. Prior to this approval, the State must demonstrate that the longer TCB sections have adequate internal (longitudinal) reinforcing.

We have reviewed ADOT's request and supporting documentation. Oregon's 12.5-foot TCB sections have been crash tested and accepted by FHWA. ADOT has demonstrated that the reinforcing steel in their 20-foot Oregon design is similar to that of Virginia's 20-foot F-shaped design. Therefore, we approve the 20-foot section of Oregon TCB for use on the National Highway System.

If you have any further questions or concerns, Jennifer Brown or Bill Vachon would be happy to discuss them with you. Please feel free to call either of them at (602) 379-3646.

Sincerely,

for Robert Hollis
Division Administrator

August 17, 2001

Mr. Daniel J. MacDonald
Standards Engineer
Oregon Department of Transportation
222 Transportation Building
Salem, Oregon 97310

Refer to: HSA-10/B-86

Dear Mr. MacDonald:

The information on the Oregon precast barrier that you sent with your May 25 letter was forwarded to my staff for review. Although the tested barrier, an 810-mm tall, 3.84-m long F-shape barrier with a pin and loop connection, appeared to meet all evaluation criteria contained in the National Cooperative Highway Research Program (NCHRP) Report 350 at test level 3 (TL-3), the test report, prepared by KARKO Engineering Automotive Research Center, did not contain all of the information recommended in Chapter 6 of NCHRP Report 350. The most obvious omission was the lack of a detailed description of the test article, including internal reinforcing and connection details, and there were questions concerning the accuracy of some of the data.

On July 26, you sent Mr. Richard Powers copies of revised reports, both for the original 810-mm barrier (Test Report No. KAR21007-01) and for a subsequent test of a 1065-mm tall precast concrete barrier (Test Report No. KAR21007-02). Descriptions of each of these designs and their crash performance are as follows:

Standard barrier: test installation consisted of 16 precast concrete F-shape segments, each 810-mm high, 3.8-m long, 610-mm wide at the base, and 240-mm wide at the top. The pin and loop connection consisted of two 19-mm A36 steel loops near the top of one segment end, above a single 19-mm steel loop near the bottom on the same end. The corresponding loops on the adjacent barrier segment consisted of a single loop near the top and double loops on the bottom. When placed together, the single loops fit between the double loops, forming two connection points, each consisting of three loops. A 25-mm diameter, 735-mm long ASTM A449 steel pin, with no nut or retention device, was dropped through the loops to complete the connection. This system was impacted near its midpoint with a 2000-kg pickup truck at 100.7 km/h and a 25 degree angle. Occupant impact velocity was reported to be 5.8 m/sec and maximum 10-millisecond ridedown acceleration was 18.2 g's. The maximum roll angle of the vehicle was less than 15 degrees and the barrier dynamic deflection was only 762 mm. This design is shown in Enclosure 1.

Tall barrier: test installation consisted of 20 precast concrete F-shape segments, each 1065-mm high, 3.02-m long, 660-mm wide at the base, and 230-mm wide at the top. The connection between segments consisted of two sets of two perforated C-shape steel channels with the open sides alternately positioned such that one leg of each channel fits between the legs of the mating channel on the adjacent barrier segment. A 25-mm diameter ASTM A449 end bolt, 760-mm long, was inserted through holes in each C-channel leg and into a nut welded to the bottom of the lower C-channel, effectively forming eight points of connection. This system was impacted near its midpoint with a 2000-kg pickup truck at 102.4 km/h and a 25 degree angle. Occupant impact velocity was reported to be 6.2 m/sec and maximum 10-millisecond ridedown acceleration was 19.4 g's. Maximum vehicle roll was approximately 16 degrees and the barrier dynamic deflection was 813 mm. This design is shown in Enclosure 2.

Based on the reported results of the tests run on these barriers, both the 810-mm tall and the 1065-mm tall designs are considered to meet the evaluation criteria of the National Cooperative Highway Research Program (NCHRP) Report 350 at test level 3 (TL-3) and may be used on the National Highway System when such use is acceptable to the contracting authority. Both barriers exhibited the least amount of deflection and resulted in the most stable, post-impact vehicle trajectories of any free-standing, precast barrier tested to date. I understand that the drawings for these non-proprietary barriers can be obtained by contacting you at (503) 986-3779 or from your web site at <ftp://ftp.odot.state.or.us/techserv/roadway/standards> under drawing nos. odot_apwa500.pdf and odot_apwa545.pdf.Sincerely yours,

(original signed by Frederick G. Wright, Jr.)

**Frederick G. Wright, Jr.
Program Manager, Safety**

2 Enclosures



U.S. Department
of Transportation

**Federal Highway
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

JUL 17 2000

Refer to: HSA-B70

Milford L. Miller, P.E./L.S.
Standard Drawing Engineer
State of Idaho Transportation Department
P.O. Box 7129
Boise, Idaho 83707-1129

Dear Mr. Miller:

In your June 20 letter you requested formal Federal Highway Administration acceptance of the Idaho Transportation Department's 6095-mm (20-foot) long precast concrete barrier for use on the National Highway System (NHS) as a test level 3 (TL-3) barrier. To support your request, you also sent a copy of an April 2000 test report prepared by E-TECH Testing Services, Inc., in Rockland, California, entitled "NCHRP Report 350 Crash Test Results for the Idaho 6095-mm Concrete Barrier" and a video tape of the two tests that were conducted.

The barrier you tested was a standard New Jersey profile concrete barrier 810-mm (32-inches) tall and 6.095-m (20-feet) long. The base width was 610-mm (24 inches) and the top width was 150-mm (6 inches). Each segment weighed approximately 3630 kg (8000 pounds). Adjacent segments were connected using 3 1.8-mm (1.25-inch) diameter steel pins passed through four loops made from 19-mm (.75-inch) diameter steel bars. Longitudinal reinforcement consisted primarily of six no. 16 bars per segment. Two different connection designs were tested. The first consisted of galvanized 32-mm (1.25-inch) diameter by 638-mm (25-inch) long A307 hex bolts secured by 32-mm (1.25-inch) A536 heavy hex nuts. Two F844 Wide Type A washers were used, one under the bolt head and one above the nut. Enclosure 1 is a schematic drawing of this connection detail. The connection in the second test was a 32-mm (1.25-inch) diameter A36 steel pin that was 660-mm (26-inches) long. No locking nut or other pin retention device was used in this design. The steel loops were identical in both tests.

Staff members have reviewed the results of the two tests you conducted and concur with your assessment that appropriate NCHRP Report 350 evaluation criteria were met. They also agree that it is not necessary to test the 860-kg car since the barrier is identical to California's K-Rail which was successfully tested with the small car. The summary results of each test are shown in Enclosure 2. Maximum permanent deflection was 1.0 m with the bolted connection and 1.1 m with the pinned connection. The test installation was 73.2 m long and

the pickup truck impacted 1.2 m from the mid-point in both tests. Impacts nearer the ends of an installation would be expected to increase the deflection distance under similar impact conditions. Based on these test results, the Idaho Concrete Barrier, with either the bolted pin connection or the drop-pin connection, may be considered acceptable for use as an NCHRP Report 350 TL-3 barrier on the NHS when such use is requested by a State transportation agency. I understand that this design remains nonproprietary and that anyone wanting to obtain detailed specifications and plan sheets for this barrier (can request them by calling you directly at (208) 334-8475.

Sincerely yours,



Frederick G. Wright, Jr.
Program Manager, Safety

2 Enclosures

APPENDIX D: CONSULTANT REVIEW REPORT



University of
Nebraska
Lincoln

REC'D JAN 23 2002

Midwest Roadside Safety Facility
Civil Engineering Department
W328.1 Nebraska Hall
P.O.Box 880529
Lincoln, NE 68588-0529

January 10, 2002

Muhannad Al Zubi
Traffic Group
Arizona Transportation Research Center
1130 N. 22nd Ave., 075R
Phoenix, AZ 85009

Re: ADOT TCB Design

Dear Mr. Zubi:

Selection of a design for a temporary concrete barrier standard is not a simple task and ADOT's Traffic Group should be commended for their efforts conduct a thorough evaluation of available alternatives in such a short period of time. As summarized in Attachment 1, evaluation criteria used by MwRSF are quite similar to those used by ADOT in making their selection. ADOT's final recommendation appears to be reasonable and appropriate. After carefully reviewing the ADOT's proposed implementation plan, the MwRSF would recommend only two changes, 1) change the specification of the steel loops used in the Oregon barrier, and 2) eliminate the provision for incentives for early conversion to the new design.

Iowa adopted the an NCHRP Report 350 compliant barrier at a very early stage and implemented on a year round construction project. Their accident experience with a TCB design utilizing A615 steel in the steel loops has shown that this material can become brittle at temperatures near 20-30° F. Subsequent testing of these steel loops showed a glass transition temperature of the steel well above 20° F. Further testing of a variety of steels, including weldable rebar, has identified only two that reliably provide good fracture toughness at low ambient temperatures. If ADOT expects that its barrier will be deployed in regions that experience temperatures in the 20-30° F range or below, it is recommended that the steel loops be constructed from one of the two fracture resistant steel specifications shown below.

ASTM A-709, HPS 70W, S84, Zone 2

or

MMFX-2 microcomposite steel
MMFX Steel Corporation

In an effort to explore the need for rapid conversion to Report 350 compliant barriers, a number of states, including Washington and Kansas, have conducted detailed evaluations of the field

Muhanned Al Zubi
January 10, 2002

Page 2

performance of their existing TCB systems. All of these studies have clearly shown that older TCB systems, even those that cannot meet NCHRP Report 230 evaluation criteria, exhibit excellent in-service performance. The Washington experience is especially relevant to ADOT's situation because the Washington TCB design used a pin and wire rope joint very similar to ADOT's and their barrier was used in both temporary and permanent applications. Washington found that the accident history of their TCB compared favorably with that of permanent concrete safety shaped barrier. Kansas found that even a barrier system with no joint moment capacity could provide safety performance similar to permanent concrete barrier when the TCB is used exclusively in construction zones. Obviously, this favorable accident experience is not an indication that the TCB performs as well as permanent barriers, but instead it indicates that, for the situations where it is most often utilized, such as tight construction zones, it can provide adequate protection for motorists. Based on these findings, we do not believe that any incentive payments made to quickly replace a barrier system that could likely meet NCHRP Report 230 impact criteria, would be cost beneficial. Note that this evidence is not an indication that Report 350 TCB systems are not cost beneficial because several of the existing systems cost no more than many of the older TCB designs. Hence the primary cost of implementing Report 350 TCB systems is associated with the actual transition to the new design and, in our opinion, every effort should be made to minimize that cost.

I hope that this review has addressed all of ADOT's concerns. Feel free to call me at (402)-472-9332 if you have questions or need additional information.

Sincerely,



Dean L. Sicking, Ph.D., P.E.
Director

Attachment 1
Selection of Temporary Concrete Barrier Designs

The selection of a temporary concrete barrier should be based on a number of considerations, including safety performance, operational efficiency, initial cost, and durability. Each of these considerations has a number of different components as summarized below.

Safety Performance - Safety performance of a temporary concrete barrier design has a number of components, including vehicular impact performance, barrier shape, barrier deflections during impacts, and low temperature performance. Impact performance of TCB designs is evaluated through a single full-scale crash test with a 2000 kg (4400 lb) 3/4 ton pickup impacting the barrier at 100 km/hr and 25 deg. Assuming all barriers under consideration have passed NCHRP Report 350 testing, the comparison of impact performance is primarily based on measures of how close the barrier systems are to failing the test. Since vehicle rollover is the most frequent cause of test failures for TCB systems, the surrogate measures of the risk of rollover, including height of vehicle climb and maximum roll angle during the test, are the primary yardsticks for measuring relative safety performance. Testing of the Oregon TCB system showed very low roll angles and very low vehicle climb for the NCHRP Report 350 testing. In fact, the safety performance of this barrier has to be considered to be the best of all TCB's tested thus far under Report 350 criteria.

Although the impact performance of a TCB has to be considered the most important measure of safety performance, the comparison of systems that have passed NCHRP Report 350 testing may not be straight forward. There are significant variations in the configuration and condition of 3/4 ton pickups used as test vehicles under NCHRP Report 350. These variations can significantly effect the relative safety performance of different barrier systems. Therefore modest differences in impact performance should not be overweighted.

The shape of a TCB design will have a major impact on impacts that involve lower angles of approach than those used in full-scale crash testing. Research has shown that risk of vehicle rollover is still very high for high speed impacts with safety shaped barriers even when for low approach angles. A number of research studies have shown that the F-shape concrete barrier reduces the risk of rollover over a wide range of impact conditions when compared to New Jersey shaped barrier. Although the it is unclear whether the single slope barrier provides incremental improvement over the F-shape barrier for temporary applications, one research study has indicated some improvement for permanent barriers. Therefore, it can be concluded that both the F-shape and single slope barriers are generally desirable over the New Jersey shape, but it is unclear whether the single slope is better than the F-shape for TCB applications. Since the Oregon design utilizes an F-shape configuration, it can be considered to have the highest possible rating in the shape category.

Deflections of TCB's during severe impacts can pose a risk to workers standing behind the barrier. It should be noted that for real world applications, the risk of a worker standing right behind the barrier in close proximity to the point of impact is relatively low. Never-the-less deflection distance during severe impacts should be considered during the selection process.

Again the Oregon design leads all other TCB systems tested to date with deflections of 30-32 inches.

The final safety consideration for TCB systems is its low temperature performance. Real world accident experience has shown that when TCB's are deployed in cold weather, steel rebar materials used in pin and loop systems can become brittle. Iowa DOT has reported many incidences of steel loop fracture during a single winter when their pin and loop barrier was deployed through Des Moines. MwRSF research has shown that this problem is related to the broad range of chemistries allowed in the ASTM A615 specification for reinforcement steel. Although some heats of A615 will exhibit excellent cold weather fracture toughness, many heats do not. This same testing has shown that A615 can be expected to perform adequately whenever ambient temperatures do not reach the 20-30° F range. Alternate steels must be used to eliminate this low temperature brittleness problem. Both ASTM A-709, HPS 70W, S84, Zone 2 steel and MMFX-2 microcomposite steel from MMFX Steel Corporation exhibit the low temperature toughness required to prevent this problem.

It should be noted that although Report 350 TCB designs should provide improved safety performance compared to older system, the improvement may not be sufficient to justify scraping usable barriers that could meet NCHRP Report 230 standards. In an effort to explore the need for rapid conversion to Report 350 compliant barriers, a number of states, including Washington and Kansas, have conducted detailed evaluations of the safety of their TCB systems. All of these studies have clearly shown that older TCB systems, even those that cannot meet NCHRP Report 230 evaluation criteria, exhibit excellent in-service performance. The Washington DOT examined the safety performance of their TCB in both temporary and permanent applications. The Washington design used a pin and wire rope joint with 10 and 12.5 ft segment lengths. Washington found that the accident history of their TCB compared favorably with that of permanent concrete safety shaped barrier. Kansas found that even a barrier system with no joint moment capacity could provide safety performance similar to permanent concrete barrier when the TCB is used exclusively in construction zones. Obviously, this favorable accident experience is not an indication that the TCB systems perform as well as permanent barriers. Instead these studies indicate that, for the situations where it is most often utilized, such as tight construction zones, TCB can provide adequate protection for motorists. Note that this evidence is not an indication that Report 350 TCB systems are not cost beneficial because several of the existing systems cost no more than many of the older TCB designs. Hence the primary cost of implementing Report 350 TCB systems is associated with the actual transition to the new design and, in our opinion, every effort should be made to minimize that cost. Since the overall costs of the new barriers will be very similar to the old designs after the transition is complete, implementation of the Report 350 barriers will be very cost beneficial even though the existing designs provide relatively good field performance. In light of the desire to minimize the cost of implementing the new barrier design and the modest safety performance improvement that can be expected, the MwRSF recommends that ADOT eliminate the proposed incentive payments for early replacement of existing TCB segments.

Operational Efficiency - Operational efficiency refers to the level of effort required to transport, deploy, remove, and replace the barrier system. Transportation of the heavy barrier segments is perhaps the biggest cost associated with the implementation of any TCB.

Transportation costs are directly proportional to the number of truck loads required to deliver the needed length of barrier and TCB weight controls the amount of barrier that can be transported per load. Therefore the weight of the barrier system per unit foot is an important consideration. TCB designs tested to date weigh from 430 to 600 lb/ft. The low and high ends of this weight scale are represented by the Iowa and Georgia TCB designs, respectively. Approximately 125 ft. of the Iowa barrier can be transported per load while only 90 ft. of the Georgia system can be placed on a single truck. The 32 in. high version of the Oregon barrier weighs approximately 481 lb/ft and limits the system to approximately 112.5 ft of barrier per truck load. Although the Oregon design does not have the lowest transportation cost of any system, its weight is not unusually high.

Barrier deployment is another operational factor that effects the cost of TCB implementation. The cost of deployment is primarily associated with the cost of the equipment and workers involved in the operation. Therefore, cost of this operation is directly proportional to the time spent deploying a barrier. The procedure can be divided into three different tasks, offloading, placement, and attachment. Note that all of these measures are segment based and the overall segment length does not greatly influence any of the activities. Therefore, if all other features are the same, designs that incorporate longer segments will have lower deployment costs. Further, since many research studies have shown that longer segments provide improved safety performance, increasing the segment length should be an option for all TCB designs. The time required to offload a barrier segment is relatively constant from one system to the next and therefore is not an important consideration. Placement of barriers can be influenced by the joint design and some variation would be expected among the various designs. Pin and loop joints have been found to be relatively easy to place and therefore the Oregon design would have a low placement time. Attachment of adjacent barrier segments is another procedure where pin and loop systems have relatively low deployment times. The only real variation among pin and loop barriers is that some designs require a retainer to be placed at the base of the pin. This operation does add to the attachment time. Since the Oregon barrier utilizes a pin and loop design without a retaining pin, its deployment costs should be as low as any non-proprietary system.

Removal and replacement of a TCB system mid-way through a construction project is has the same placement and attachment considerations as discussed above. The primary difference for this operation is that frequently the barriers are moved only a short distance and a fork lift is the best tool for this task. In this case, segment weight becomes an important consideration. Small fork lifts cannot be used to remove and replace heavy segments. Although the Oregon barrier is again not the lightest system, its weight would not preclude the use of fork lifts for moving the TCB.

Initial Cost - TCB fabrication costs have been found to be controlled largely by the joint and the weight of the barrier. Barrier joints comprise a significant portion of the cost of a TCB design because of the labor and materials associated with the fabrication. Research has shown that pin and loop designs are generally on the low end of the joint cost spectrum because the fabrication is relatively simple and the material costs are relatively modest. Features that increase the cost of these systems include multiple loops and pin retainers. Since the Oregon TCB design incorporates six loops per joint and no retaining pin, its costs would be considered to be in the middle of the range for pin and loop systems. Most other joint designs are proprietary and/or more costly to fabricate.

The weight of a TCB has a modest influence on its cost because additional weight always means additional concrete in the barrier cross-section. However, economic analyses of temporary barrier systems have indicated that barrier weight is not as important as joint fabrication. The moderate weight of the Oregon design again places it in the middle of the range of TCB's that have met NCHRP Report 350 criteria.

Durability - Historical research has shown that most TCB segments taken out of service are damaged during the process of placement or removal rather than as a result of a barrier impact. This type of damage most often occurs when adjacent segments are slammed together by lifting equipment. The only method of reducing this type of damage is to provide adequate shear reinforcement near the ends of the barrier and eliminate thin sections of concrete that are sometimes created by lifting slots at the base of the barrier. Although it is difficult to predict barrier durability during handling, the Oregon design appears to be as likely as any pin and loop design to perform well.

Durability during an impact is also an important consideration. Under the extreme impact conditions associated with Report 350, the Oregon design appears to have fared very well during full-scale crash testing. Therefore, this design should exhibit good resistance to damage arising from vehicular impact.

In summary, the Oregon temporary concrete barrier design represents the best impact performance, one of the safest shapes available, and its simple joint and moderate weight make it no more costly than the average of barriers that have been successfully tested to meet NCHRP Report 350. The only way to reduce the cost of the system would be to implement a lighter cross-section, such as that used by the Iowa TCB. FHWA has indicated that it would soon adopt a policy allowing agencies to incorporate the best features of all barriers that have been tested. When this policy is implemented, ADOT may consider reducing their cross-section to match the Iowa design. As summarized above, the only changes that are recommended to ADOT's proposed implementation plan is to change the specification for the steel used in the barrier loops if the system will be used in cold weather and eliminate the incentive payments for early elimination of the existing TCB barrier design.

REFERENCES

1. FHWA Policy Memorandums - Office of Engineering, 07/25/97 OPI: HNG-14
“Identifying Acceptable Highway Safety Features”
(<http://www.fhwa.dot.gov/////legsregs/directives/policy/ra.htm>).
2. H.E. Ross, JR., D.L. Sicking, R.A. Zimmer and J.D. Michie
”National Cooperative Highway Research Program, Report 350, Recommended
Procedures for the Safety Performance Evaluation of Highway Features,”
Transportation Research Board, 1993.
3. Charles F. McDevitt, "Basics of Concrete Barriers" Public Roads, v. 63, no. 5
March/April 2000 pages 10-14 (TD 2.19:63/5).
(<http://www.tfrc.gov////////pubrds/marapr00/concrete.htm>).
4. FHWA Approval Letter - Oregon Compliant Design – 08/17/01 HAS-10/B-86
(http://safety.fhwa.dot.gov/fourthlevel/hardware/barriers/pdf/b_86.pdf)