Applied Research and Innovation Branch

Feasibility Study of Developing and Creating a Standardized Subset of Bridge Plans

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16. Abstract

This study investigated sizes and geometry of existing bridges in Colorado and investigated standard bridge systems used by other entities. The study proposed standard bridge types advancing the goals of SHRP 2 R19A & B, the rapidest ABC construction, and encompassing a wide range of span and structure lengths and widths, with the capability of a wide range of skews while preserving, to the extent possible, simplicity, low construction cost and a competitive contracting environment, in order to achieve the largest practical benefit to Colorado's bridges over the coming decades. For Colorado these are pre-decked simple made continuous precast girders, and shaft and precast cap substructures, all made integral with details emulative of CIP construction. These are made practical by an effort to control camber and camber variations by design and by monostrand post-tensioning camber adjustment.

Implementation is planned to be progressive, starting from worksheets for standard superstructures and substructures in conjunction with prototype structures, expanding to encompass more acute skews, and finally, additional worksheets incorporating the design information to accommodate the full range of anticipated structure types, spans, span arrangements, and skews without additional detailed structural design or details for each individual bridge element. At this time, a worksheet can be developed to allow simplified presentation of the desired structure. Minor organizational changes are proposed to ensure continuity of the development and maintenance of these worksheets. Rough estimated implementation costs and value of benefits are included.

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Executive Summary

The objective of this study is to determine if the development of a standardized subset of bridge plans is feasible and cost effective. The past 30 years of successful Colorado Department of Transportation (CDOT) bridge design can be used as a starting point to create a standardized subset of bridge plans. This proposed subset of standardized plans is a means to implement CDOT and Federal Highway Administration (FHWA) mandates: Every Day Counts (EDC), Accelerated Bridge Construction (ABC), and Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS).

The study included six major steps:

1. Literature review of past practice in Colorado and elsewhere
2. Project standardized bridge needs and usage using historical CDOT PONTIS data
3. Set standard parameters for standard design and development
4. Identify bridge elements to standardize
5. Estimate cost to develop standards and savings generated by the standards
6. Provide recommendations

State DOT’s, including CDOT, have relied on various levels of bridge standardization ranging from standard details to work sheets and standard plan sets. Significant effort can be expended to provide robust standardization as illustrated by the Texas DOT’s comprehensive set of bridge standard plans. Other states limit their development to standard details or worksheets, such as those by CDOT. The decision of how far to develop these standards should be based on projected usage and return on the investment to develop them measured by savings in bridge design and detailing, construction, and life cycle cost. The cost of standardization should also include maintaining the standards so that design code and practice changes can be incorporated along with evolving material and construction capability.

The estimated number of on-system bridges annually constructed by CDOT is 36 based on projecting the CDOT PONTIS data forward; the study was limited to on-system (state road) bridges. The data was then reviewed to project the range of span lengths and skew angles expected per year. About 58% of the bridges, or 21 per year, are expected to fall within span and skew angle ranges suitable for standardization.

Three new bridge superstructure types were then developed to cover the span and skew ranges:

1. Short spans to 65 feet – precast decked slabs
2. Medium spans to 146 feet – precast deck U-girders
3. Long span to 199 feet – decked BT girders

All three superstructure types are pre-decked with the top portion including a full thickness deck slab as part of the precast concrete member. All three types can be configured for variable top span (or slab) widths up to 15 feet wide, eliminating cast-in-place deck construction. These superstructures can be made continuous for live load by splicing them across piers. Preliminary merit cost design span tables are included for these superstructure sections. All of these superstructures allow ABC and the decked slabs are especially suitable to GRS-IBS applications. These superstructures can also reduce the structure depth.

A conceptual-level assessment of substructure standards was also undertaken with the focus on ABC and reduction of design and construction costs. Precast concrete pier and abutment elements such as

caps, columns, stems, and wingwalls have the most probability of being cost effective as well as accelerating construction.

Utilizing historical design costs and projecting standard usage based on the historical CDOT bridge construction data, significant design savings were identified. It is estimated that at up to 1/3 of preliminary design and 2/3 of final design costs could be saved using well-developed and complete bridge standards. The savings could be as high as $500,000 per year in design costs with the potential for additional saving in construction and life cycle cost generated by the standardization. An additional $340,000 per year could also be achieved by using elements of these standards on bridges with spans or skews outside the standard plan ranges.

Standard plan development stages are:

1. Worksheet for moderate bridge skew
2. Expanding worksheets for larger skews
3. Integrate partial standard plans for full plan set generation
4. Yearly maintenance

Because the CDOT on-system yearly bridge construction program is not very large, only development of a few standards to worksheet level is recommended at this time. These include decked slab bridge superstructures, decked U-girder superstructures, decked BT-girder superstructures, and the precast substructure worksheets to go with them. Future expansion of the standards can include extending skew angle capability, adding integrated partial plans that provide enough data to convert worksheets to full standard plans requiring no design and little detailing effort to complete.

The estimated cost to develop the standards varies with the level and commitment to standardization. The estimated costs to develop and implement the recommended superstructure and substructure worksheets are:

Type	Worksheet Level	Incl. Larger Skews	Incl. Integrated Partial Plans	Yearly maintenance
Decked Slab	$255,000	$330,000	$576,000	$29,000
Decked U-Girder	$345,000	$468,000	$822,000	$41,000
Decked BT-Girder	$417,000	$525,000	$912,000	$46,000

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1. PROJECT SCOPE

The Colorado Department of Transportation (CDOT) contracted with Atkins to assess the feasibility of developing standard bridge plans. This study was prompted by the long time and substantial cost required to complete the design of bridges. The ability to have pre-designed structures that can be selected, specified, and estimated quickly will help to reduce the cost and time required for more traditional design practices.

In order to control the cost and time for the study, some limitations were set for the work including:

- Only bridge types easily suited to accelerated bridge construction (ABC) were considered. For superstructure these were limited to structures in which the deck is a part of the pre-manufactured girders, i.e. cast-in-place deck construction is not required.
- Due to the current local non-competitiveness of steel superstructures, this type of bridge was not included in depth. The limited investigation revealed limitations that would impede broad implementation in Colorado of standard steel bridges that would meet the design goals. Foremost among these limitations is a lack of local steel bridge fabricators. See Section 6.5 and information in the CD for additional information.
- Existing structure data used in the study was limited to on-system CDOT bridges. Off-system bridges are explicitly not included in this project; however, standards designed and implemented for state highways will be appropriate for off-system use.
- Only rudimentary recommendations were included for developing substructure standards.

The project scope of work included six major steps:

1. Literature review: Search for and review of bridge standard data and procedures used by Colorado and other state DOTs.
2. Project need and usage: Collection of all on-system bridge data in the CDOT inventory and analysis of this data to project the type and scale of CDOT bridges to be designed and constructed over the next 20 years. Note that this started with a limited data set of the bridges along I-70, I-25, US 36, and state highways, but was expanded to all on-system bridges during the study.
3. Set standard parameters: Determination of expected standard bridge widths, skews, and typical sections needed for the next 20 years. Propose design methodology. A relatively narrow typical section suited to state highways with the lowest traffic volumes and many off-system needs is also included.
4. Identify Superstructure Elements: Perform a conceptual design of decked precast concrete sections suitable for on-system roads, ABC, and splicing over piers to extend spans and control camber. Develop a graph illustrating span capabilities. Identify substructure configurations suitable for ABC.
5. Estimate Costs: Estimate costs to develop and maintain standards and project a breakeven timeframe to recoup the investment.
6. Recommendations: Provide recommendations for development, use, and maintenance for bridge standards.

The project scope of work does not include:

- Concrete box culverts (CBCs): CDOT already has an adequate and up-to-date standard (Miscellaneous or M-standard) for CBC construction. We recommend that CDOT consider updating this standard as it currently is not suitable for Accelerated Bridge Construction (ABC), cell widths do not accommodate all practical sizes, and the top slab details do not accommodate using the top slab as a deck on grade with the bridge rails following the grade.
- Currently-used precast pre-stressed beams, steel beams, and cast-in-place concrete bridges: A goal of the study is to assess the feasibility for standards use for future design and construction. To be effective, the study focuses on updated superstructure geared toward use in ABC as well as with innovative substructure such as GRS-IBS bridges. This focus on future needs eliminates the assessment of currently used superstructure elements not as useful for ABC or GRS-IBS structures. This does not mean that these other types not included could not be effectively standardized, just that they do not fully meet the goals for standard bridges included in this report. The major goal not fully met is the highest level of ABC. Should such standards be subsequently created, they could be included in projects as contractor alternates when ABC is not needed for those cases there they meet the projects requirements.

2. CDOT STANDARD PLAN HISTORY

The Colorado DOT currently has M-Standards (Colorado Miscellaneous Standard Plans) for culverts, bridge worksheets for various bridge elements, and design aids in the CDOT Bridge Design Manual. These tools have been used quite successfully, but have not been fully developed and are outdated for design code changes and practice. The worksheets include a large selection of precast girder types, bridge rails, joint details, bearing details (excluding integral details), approach slabs, and some precast stay-in-place deck forms. There is little standard detailing information available for decks (except the precast deck forms), framing plans, steel girders, wingwalls, piers, and abutments, although there is an integral CIP concrete abutment detail and guidelines in the CDOT Bridge Design Manual that have been followed as a standard for some time. In the 1930's CDOT developed standard plans for truss superstructures and timber bridge spans that were very heavily used during the highway building program of the 1930's, but these structure types gradually became obsolete as more modern bridge types were developed.

In the late 1950's and early 1960's, during the early days of the interstate highway design program, a large number of CDOT bridges were not detailed separately, but used modified plans from similar bridges. The similar bridge plans were copied and archived and then the dimensions and reinforcing information changed directly on the original drawing, effectively reusing it. This method was effective, but required a stock of recent similar original plans that covered a significant portion of the types, spans, and substructure arrangements being used. Even then, these projects still required work to select the appropriate original plan set to change and to design the needed changes. This process would be difficult to repeat now due to rapidly changing codes and CAD programs. Circumstances also make it difficult to find a current bridge design similar enough to re-use. While this practice of modifying served its purpose at the time, it did provide CDOT a basic understanding that standardization could be beneficial.

CDOT's next attempt at standard bridges occurred in the 1980's when CDOT developed standard plans for precast twin-tee superstructures. These bridges were only suitable for lightly trafficked roads without heavy truck traffic or de-icing use and were used mostly by counties. Eventually CDOT transferred responsibility for non-state highways to cities, towns, counties, and municipalities, absolving their design responsibility for these off-system facilities. Because of this transfer of responsibility, CDOT no longer maintained or upgraded these standards. This is indicative of one of the issues with this kind of standardization; to be effective over the long term, standardization needs a broad applicability, often achieved with a degree of conservatism by creating a structure to meet the most stringent needs when something simpler or less robust would suffice. Fortunately, this can have compensating advantages in reduced maintenance, delayed obsolescence, and a longer structure life in the face of changing use. Also, any standards created need to be maintained to reflect changing codes, exposed deficiencies, improved presentation, and extended applicability.

In the early 1990's, CDOT initiated a bottom-up effort to automate detailing to take advantage of CAD to speed production. This advanced to the point of automating the detailing and some of the design of integral abutments and their wingwalls, which is a considerable part of the detailing effort on a bridge. This automation effort failed principally for two reasons:

1. The constant changing of the CAD program (AutoCad) it was based on, and

2. The cost of training, documentation, and coordination with design consultants that would have been required.

These two factors made the cost of automated detailing more than the savings that could be produced.

In 2005, CDOT undertook an effort to create an automated bridge-detailing system using software from CEC Engineering of Columbus Ohio. The software seemed to be effective at producing drawings, but was not integrated with any design programs, and required considerable effort to provide required input data. CDOT estimated that it might save 30 percent on plan production time when an inexperienced CAD detailer was used, but there would be little savings with a more experienced detailer. Ultimately, the automation effort ended without producing any production plans and was terminated when CDOT changed their CAD platform to MicroStation; CEC's software only worked with AutoCAD.

For a computer aided design and detailing (CADD) program for bridges, the relationship between the programming and program maintenance effort and the benefit might shift if detailing standards (fonts, sheet borders, dimensioning standards, layering, line color and width, etc.) and the types of structures and details were standardized nationally rather than State by State or organization by organization.

M-Standard culverts existed in one form or another as one, two, or three span units starting in the 1930's. In the late 1970's and early 1980's there was an effort to update the design based on rigid frame action and the then-new AASHTO Load Factor Design code method, but a code change made the software obsolete. It was only recently that the culvert M-standards were finally updated to the LRFD code. In the interim, there were some changes to better accommodate skew and to reduce the scour vulnerability of wingwalls.

Worksheets grew from the plan copying efforts of the 1960's. Commonly used details were placed on separate sheets that could be reproduced and used or altered as needed. Since that time if the details needed for plan sheets had been used repeatedly, or it was anticipated that they might be used repeatedly and detailed so that little customization would be needed, then the details were prepared as a worksheet. Some of the worksheets developed failed to see repeated use. Generally worksheets created as part of an actual project design achieved continued reuse, probably because actual project needs shaped what was designed and how it was presented, and also because the details were thoroughly checked. Most often, a worksheet was created for the second use of a detail, when it was clear from the first use that the detail was useful and the worksheet could save effort. The first effort shaped what the detail needed to be, and the second how to develop the worksheet so as not to require significant effort to use it in differing structures.

There has been little effort to transform bridge design worksheets into M-standards, as there has not been a shift from seeing these worksheets as "a detail that can be used" to "a detail that should, when possible, always be used." Details that approach the level of confidence that they do not need to be constantly evaluated for the impact of code changes and applicability in different situations, are rare, but perhaps include bridge rails, fences, and stay in place concrete deck forms.

3. BRIDGE STANDARD USAGE BY OTHER STATES

In December 2013 and January 2014, an internet search for DOT standard plans was completed along with later discussions with several state bridge engineers. Not all DOTs have standards available on their websites or in the public domain so a complete review of all state materials was not possible. This discussion focuses on the DOT standards that are most relevant to this study. Additional information studied is included in the attached CD.

Standard plans are fully designed and detailed and only need plan sheet assembly to make a completed design package. Standard details are fully designed and detailed pieces and parts for bridges that are included in an assembly of bridge plans, but other manually generated sheets are needed to make a complete plan set. Worksheets are highly detailed plan sheets that convey desired details but do not have completed designs or details. These sheets require an engineering design and often require data to be entered to complete the sheet.

Most US states have standard details such as joints, rails, and precast girders. Even those states with fairly complete standard drawings generally do not have standard drawings for quantity summaries, general layouts, foundation plans, geology information, construction layouts, hydraulics information, and geometry information. Note that very little information was available for agencies outside the US.

3.1. Complete standard plan or standard bridge detail sets

Complete standard plans sets are fully designed and detailed and ready for construction with design, layout, or modification. Few states or provinces had complete sets of bridge standard plans; the following states and provinces have complete standard plans sets:

Alberta, Canada

Alberta has standards for slab bridges only.

Iowa

The Iowa DOT has standards for slab bridges, rolled beam bridges, and precast concrete beam bridges in three-span configuration for 24-foot, 30-foot, 40-foot, and 44-foot curb-to-curb widths. Some of these standards cover incremental skews from 0 degrees to 45 degrees. Most of these bridges are integral. Stainless or epoxy-coated reinforcement can be selected depending upon the level of durability desired. There are around 1,200 sheets of standard plan pages.

Kansas

The Kansas DOT has standards for haunched post-tensioned CIP concrete slab bridges for 28-foot, 32-foot, 36-foot, 40-foot, and 44-foot roadway widths, and up to 30-degree skews. These standards are three-span continuous bridges in four incremental lengths from 165 feet (50 feet by 65 feet by 50 feet) to 234 feet (71 feet by 92 feet by 71 feet). Not all span-length combinations are available yet. A manual is available describing the system, limits, and how to assemble the plans. The system is not useful for ABC and requires considerable falsework.

Haunching of the slabs may slightly limit future functionality of the outer parts of the spans where clearances are critical. Since the standards are cast-in-place construction, they can accommodate significant vertical curve and superelevation variations as well as modest curvature, though details may require adjustment. The spans covered in the standards must be used for layout otherwise, a full design and detail revisions will be needed.

These standards, while efficient for the shorter spans lengths, are eclipsed by precast prestressed concrete sections such as decked BT or decked U girders (described later in this report). Even the shorter CIP span lengths can be replaced by precast prestressed concrete slabs made continuous for live load at the piers.

Ohio

The Ohio DOT does not have any standard bridge plans at this time but has a very complete set of standard details (except for deck slabs or piers for non-slab structures). The Ohio DOT also has standard plans for box culverts. Research indicated that local agencies other than the DOT may be using the firm CEC Engineering for automated detailing of smaller bridges, but DOT CAD standards are now in MicroStation while the CEC Engineering program and scripts only work with AutoCAD.

Oklahoma

The Oklahoma DOT has standard details for many girder sections and bridge elements and includes guide drawings to help show the designer or detailer how to assemble bridge plans from these standard details. There are no foundation or column standard details. Skew is not addressed on most of the details.

Pennsylvania

The Pennsylvania DOT has standard details for many girder sections and bridge elements. It also has BRADD, an integrated bridge design and detailing software package. BRADD is currently limited to only simple span structures, but the state did recently upgrade the package for integral construction. The Pennsylvania DOT recently mandated that BRADD be used for all possible structures.

Texas

The Texas DOT has standard details for precast prestressed concrete I-girder bridges with 24-foot, 26-foot, 30-foot, 38-foot, and 44-foot roadway widths; 0, 15, 30, and 45-degree skews; and spans from 40 feet to 125 feet.

The Texas DOT also has standard details for decked slab bridges with 24-foot roadway width; 0, 15, and 30-degree skews; and spans from 30 feet to 60 feet. These decked slab bridge structures have discrete connectors between slab girders and therefore are not waterproof. Other states with a similar connection detail prohibit its use under heavy truck traffic due to fatigue in connectors and asphalt deterioration at the joint between girders. The Texas DOT only uses the decked-slab bridge on 24-foot wide roads with low traffic volume and its warm climate and lack of de-icer use slows down the deterioration. For sketches of these connection details see pg. 98 of NCHRP Project 12-69, “Guidelines for Design and Construction of Decked Precast, Prestressed Concrete Girder Bridges”, July 30, 2009. These decked slab bridge structures depend on asphalt to achieve road surface profile and cross slope.

In addition, Texas DOT has standard details for many structure elements, especially girder types, that, when assembled with supplementary details, can form a large part of a bridge’s plan set.

Harris County, Texas has standards based on Texas DOT slab sections and decked box sections that can be assembled into bridge plan sets. These standard plans are for spans from less than 35 feet to 110 feet in length and cover 0 and 30-degree skews. They require the bridge layout, foundation plan, and framing plan to be completed by the designer, but the remainder of the plan set is standard sheets. The deck connections have robust full-length keys and appear to be suited to higher levels of traffic and more leak resistant than the Texas DOT deck slab connections. They will not emulate cast-in-place construction so they will not be waterproof. The prestressing data is not pre-designed in these standards and must be added by the designer. The standards accommodate drilled-shaft or pile foundations.

About 20 percent of Texas DOT bridges built per year use standard plans. This is a large number of bridges per year due to the size of their program. The authors of this report believe the percentage of bridges build using standard plans in Colorado could be considerably higher than this with greater flexibility on the span lengths, number of spans, span ratios, skews, and bridge widths.

Wisconsin

The Wisconsin DOT (WisDOT) does not have any standard bridge designs at this time but does have a very complete set of standard details. Research indicated that Wisconsin is working on improving its automated design and detailing for precast concrete and steel bridges using their standard details as a framework.

WisDOT personnel have written and maintained almost all of their design and detailing software (except for RC pier) over a period of 20 years. It is used internally, but not by design consultants, for most of WisDOT's bridge plan production,. Since developing this software, WisDOT has seen an annual reduction in plan preparation costs of around $2,000,000. The software does not fully complete General Layout, Engineering Geology, and Hydraulics sheets; these sheets need additional manual work by detailers to complete. The bridge geometry program calculates and provides critical elevation information. The current focus is on 3D design and modelling with automated plan production, with the 3D data shared with contractors (software called BRIM). The WisDOT does not follow a stringent schedule for updating the software.

The Wisconsin State Bridge Engineer, who has been chair of the AASHTO T-19e computer technology committee, suggested that state DOTs considering automated plan generation should start with 3D capability or accommodate future upgrades to 3D with their software choices.

3.2. Less-complete standard plan or detail sets

Alabama

The Alabama DOT does not have any standard bridge plans at this time but does have standard details for superstructure precast-concrete girder spans, excluding piers and abutments.

Idaho

The Idaho Transportation Department (ITD) does not have any standard bridge designs at this time. ITD does have worksheets for decked girders for accelerated bridge construction (ABC), but no substructure standard details.

Massachusetts

The Massachusetts DOT does not have standard bridge plans, but recently completed several sections of its Bridge Design Manual, which includes many typical details, including those for ABC. These details are available in MicroStation format and can be pasted into drawings as they are produced. Another section of the manual is planned for completion soon.

Rhode Island

The Rhode Island DOT does not have any standard bridge designs at this time, but it does have worksheets for most bridge elements (including piers and abutments) that require design data to be filled in by the designer.

Utah

The Utah DOT does not have any standard bridge designs at this time, but it has worksheets for bridge elements geared to ABC such as precast prestressed-concrete decked girders, precast concrete piers, precast concrete approach slabs, etc.

West Virginia

The West Virginia DOT does not have any standard bridge designs at this time, but it does have a very complete set of standard details. The DOT also has worksheets for glulam bridges that require layout and girder size dimensions to be filled in.

4. DEVELOPMENT OF DATA SET USING CDOT ON-SYSTEM BRIDGE CHARACTERISTICS FOR BRIDGES CONSTRUCTED IN THE LAST 21 YEARS (1993-2013)

A twenty-one year history of CDOT's on-system bridge inventory was defined to help project future bridge design needs, costs, and type. Data was retrieved in early 2014 from the CDOT PONTIS database with the help of CDOT staff; the PONTIS data was not verified for accuracy. Some variability in coding and accuracy of the data was noticed but was deemed too small to affect the overall utility to the study and was assumed not to have a significant effect on the study conclusions and recommendations.

This section summaries and categorizes this data into bridge groupings for study use and only includes on-system bridges. Note that it was not possible to summarize the number of spans by length for this study using the PONTIS because, for multi-span bridges, only the maximum span length is recorded.

4.1. Summary information

- Total number of on-system bridges constructed = 748
- Replacements = 333
- Grade separations = 257
- Total spans = 1,905
- Total area = 11,401,530 square feet
- Total length = 183,658 linear feet, 34.8 miles
- Shortest major structure = 14 feet
- Longest major structure = 6,396 feet
- Structures greater than 800 feet long = 32 (five years had no structures constructed greater than 800 feet long)
- Longest span = 447 feet (this may be a coding error; if so the longest span is 379 feet) (nine years had no spans constructed greater than 200 feet)
- Average span = 96.4 feet
- Widest bridge = 716 feet wide out to out
- Narrowest bridge = 24 feet wide out to out
- Average width = 62 feet wide out to out

4.2. Detailed categorization of 21 year data

The following tables (Table 4-1 through Table 4-6) summarize the 21-Year PONTIS data into categories that illustrate the size and details of the CDOT bridge construction history.

Table 4-1 CDOT on-system bridges by deck area (square feet)

Type ID	Deck Area (square feet)	Portion of total	Type name
CPGC	4,033,478	42.43%	Concrete prestressed girder continuous (precast)
CBGC	948,982	9.98%	Concrete box girder continuous
CBGP	912,838	9.60%	Concrete box girder prestressed
CPG	752,626	7.92%	Concrete prestressed girder (precast)
WGCK	602,424	6.34%	Welded girder continuous and composite
SBGC	443,211	4.66%	Steel box girder continuous
CBC	411,661	4.33%	Concrete box culvert
CBGS	333,887	3.51%	Concrete box girder segmental
CTGCP	228,163	2.40%	Concrete tub girder continuous prestressed
CBGCP	210,832	2.22%	Concrete box girder continuous prestressed
RG	87,258	0.92%	Riveted plate girder
CSGCP	70,018	0.74%	Concrete slab and girder continuous prestressed (poured in place)
CSP	67,715	0.71%	Concrete slab prestressed
PCBC	60,120	0.63%	Precast CBC
CSGP	43,604	0.46%	Concrete slab and girder prestressed (poured in place)
CICK	40,385	0.42%	Concrete on rolled I-beam continuous and composite
WGC	39,977	0.42%	Welded girder continuous
WGK	34,803	0.37%	Welded girder composite
CRF	27,178	0.29%	Concrete rigid frame
CBG	21,759	0.23%	Concrete box girder
CTGP	21,048	0.22%	Concrete tub girder prestressed
CS	17,223	0.18%	Concrete slab
CMP	16,354	0.17%	Corrugated metal pipe
CSCP	12,674	0.13%	Concrete slab continuous prestressed
CIK	11,631	0.12%	Concrete on rolled I-beam composite
CSC	11,392	0.12%	Concrete slab continuous
RCPC	11,375	0.12%	Reinforced concrete pipe culvert

Table 4-2 CDOT on-system bridges by length (feet)

Type ID	Bridge Length (feet)	Portion of total	Type name
CPGC	61,140	33.29%	Concrete prestressed girder continuous (precast)
CBGCP	32,995	17.97%	Concrete box girder continuous prestressed
CBGC	14,019	7.63%	Concrete box girder continuous
WGCK	13,316	7.25%	Welded girder continuous and composite
CPG	12,510	6.81%	Concrete prestressed girder (precast)
CBGP	11,680	6.36%	Concrete box girder prestressed
SBGC	8,652	4.71%	Steel box girder continuous
CBGS	8,167	4.45%	Concrete box girder segmental
CBC	5,171	2.82%	Concrete box culvert
CTGCP	4,991	2.72%	Concrete tub girder continuous prestressed
RG	2,091	1.14%	Riveted plate girder
CSGCP	1,389	0.76%	Concrete slab and girder continuous prestressed (poured in place)
CSP	988	0.54%	Concrete slab prestressed
WGK	941	0.51%	Welded girder composite
CICK	846	0.46%	Concrete on rolled I-beam continuous and composite
PCBC	836	0.46%	Precast CBC
CRF	543	0.30%	Concrete rigid frame
WGC	512	0.28%	Welded girder continuous
CSGP	469	0.26%	Concrete slab and girder prestressed (poured in place)
CTGP	408	0.22%	Concrete tub girder prestressed
CS	333	0.18%	Concrete slab
CSGC	279	0.15%	Concrete slab and girder continuous (poured in place)
CBG	248	0.14%	Concrete box girder
CMP	200	0.11%	Corrugated metal pipe

Table 4-3 CDOT on-system bridges by number of spans

Type ID	No. of Spans	Portion of total	Type name
CPGC	560	29.40%	Concrete prestressed girder continuous (precast)
CBC	282	14.80%	Concrete box culvert
CBGCP	267	14.02%	Concrete box girder continuous prestressed
CBGC	136	7.14%	Concrete box girder continuous
CBGP	113	5.93%	Concrete box girder prestressed
CPG	110	5.77%	Concrete prestressed girder (precast)
WGCK	90	4.72%	Welded girder continuous and composite
SBGC	53	2.78%	Steel box girder continuous
PCBC	52	2.73%	Precast CBC
CBGS	43	2.26%	Concrete box girder segmental
CTGCP	33	1.73%	Concrete tub girder continuous prestressed
CMP	29	1.52%	Corrugated metal pipe
CSGCP	17	0.89%	Concrete slab and girder continuous prestressed (poured in place)
RG	15	0.79%	Riveted plate girder
CSP	14	0.73%	Concrete slab prestressed
CICK	13	0.68%	Concrete on rolled I-beam continuous and composite
CRF	13	0.68%	Concrete rigid frame
RCPC	9	0.47%	Reinforced concrete pipe culvert
CS	8	0.42%	Concrete slab
CSGP	7	0.37%	Concrete slab and girder prestressed (poured in place)
WGK	6	0.31%	Welded girder composite
WGC	5	0.26%	Welded girder continuous
CBG	4	0.21%	Concrete box girder
CSGC	4	0.21%	Concrete slab and girder continuous (poured in place)
CI	4	0.21%	Concrete on rolled I-beam
CTGP	3	0.16%	Concrete tub girder prestressed
CSCP	3	0.16%	Concrete slab continuous prestressed
CSC	3	0.16%	Concrete slab continuous
SAC	3	0.16%	Steel arch culvert
CIK	2	0.10%	Concrete on rolled I-beam composite

Table 4-4 CDOT on-system bridges by number per structure type

Type ID	No. of Structures	Portion of total	Type name
CPGC	185	32.98%	Concrete prestressed girder continuous (precast)
CBC	116	20.68%	Concrete box culvert
CPG	96	17.11%	Concrete prestressed girder (precast)
CBGP	85	15.15%	Concrete box girder prestressed
CBGCP	73	13.01%	Concrete box girder continuous prestressed
CBGC	47	8.38%	Concrete box girder continuous
WGCK	23	4.10%	Welded girder continuous and composite
PCBC	23	4.10%	Precast CBC
SBGC	16	2.85%	Steel box girder continuous
CSP	9	1.60%	Concrete slab prestressed
CRF	9	1.60%	Concrete rigid frame
CSGCP	7	1.25%	Concrete slab and girder continuous prestressed (poured in place)
WGK	6	1.07%	Welded girder composite
CS	5	0.89%	Concrete slab
CMP	5	0.89%	Corrugated metal pipe
CTGCP	4	0.71%	Concrete tub girder continuous prestressed
CBG	4	0.71%	Concrete box girder
CBGS	3	0.53%	Concrete box girder segmental
CSGP	3	0.53%	Concrete slab and girder prestressed (poured in place)
CICK	3	0.53%	Concrete on rolled I-beam continuous and composite
CTGP	3	0.53%	Concrete tub girder prestressed
SAC	3	0.53%	Steel arch culvert
RG	2	0.36%	Riveted plate girder
WGC	2	0.36%	Welded girder continuous
CSCP	2	0.36%	Concrete slab continuous prestressed
CIK	2	0.36%	Concrete on rolled I-beam composite
RCPC	2	0.36%	Reinforced concrete pipe culvert
CI	2	0.36%	Concrete on rolled I-beam
CSC	1	0.18%	Concrete slab continuous
CSGC	1	0.18%	Concrete slab and girder continuous (poured in place)
WG	1	0.18%	Welded girder
SBG	1	0.18%	Steel box girder
CDTPG	1	0.18%	Concrete double-tee prestressed girder
CAC	1	0.18%	Concrete arch culvert

Table 4-5 CDOT on-system bridges by width of structure

Width (feet)	Number of structures	Number of spans	Total length (feet)	Total area (square feet)
0-16	13	22	431	0
16-32	36	106	12,671	375,378
32-47	271	734	82,787	3,402,324
47-63	212	289	30,102	1,666,074
63-78	87	197	16,415	1,164,258
78-94	73	177	13,615	1,173,479
94-109	46	126	8,052	792,188
109-125	33	72	6,455	760,058
125-140	27	66	5,652	746,772
140-156	16	36	2,695	394,336
156-171	11	24	1,413	230,461
171<<	21	56	3,367	697,013

Table 4-6 CDOT on-system bridges by skew angle

Skew angle (degrees)	Number of structures	Number of spans	Total length (feet)	Total area (square feet)
0-7 (0)	361	948	92,518	5,361,936
8-22 (15)	125	260	24,055	1,808,261
23-37 (30)	113	281	22,508	1,512,798
38-52 (45)	86	212	18,930	1,255,332
53-67 (60)	30	68	6,958	409,873
>67	3	5	449	21,170
Varies	29	132	18,389	1,041,987

4.3. Conclusions

The following tables break down the structures by span ranges appropriate for the three recommended types and by skew and maximum span to help in determining the likely use of each recommended type and degree of skew, and thereby the cost/benefit of various levels or stages of implementation. This only includes structures suitable for standard bridges, i.e. structures less than 800 feet long, greater than 20 feet long, skew less than 50 degrees, less than 78-foot width, and greater than 16-foot width.

The PONTIS data categorization was used to determine characteristics of constructed CDOT bridges to identify expected bridge needs by span and define groups of bridges appropriate for future standard development and use. Table 4-7 summarizes the bridge group data segregated by span length and skew angle. To refine the data further, two groupings of skew angle were chosen. The groups chosen are expected to have the highest probability of standardization; they provide convenient groupings for developing standard structure elements.

Table 4-7 CDOT on-system bridge groups targeted for standardization (21 year data)

Group	Max. span length (feet)	Skew angle (Degrees)	Total No. of Spans	Total Length (feet)	Total Area (square feet)
Short Spans	0*-65	0-25	192	5,062	254,252
		26-50	37	1,066	51,741
Medium Spans	66-146	0-25	414	42,413	2,106,292
		26-50	193	18,865	891,154
Long Spans	147-199	0-25	74	11,535	517,337
		26-50	37	5,599	28,222
21 YEAR TOTAL			**947**	**84,540**	**3,849,000**

**Single spans less than 20 feet are considered minor structures and are typically concrete box culverts. While the study still considers these bridges in the group data, development of superstructure sections has been limited to spans greater than 20 feet in length.*

Note that only 42 bridges have span lengths greater than 199 feet. Structures with this length span are usually difficult to standardize, so bridges with these span lengths are not considered for standardization.

Future annual construction numbers for CDOT on-system bridges are assumed to follow the same pattern as the 21-year data period. These projections will be used to determine feasible standard bridge sections and estimate the costs to develop, implement, and maintain them. Table 4-8 summarizes the expected average yearly bridge construction needs and defines the bridge data used to complete the study.

Table 4-8 Expected average yearly CDOT on-system bridge construction study data

Group	Max. span length (feet)	Skew angle (Degrees)	Total Deck Area (square feet)
Short Spans	0*-65	0-25	12,107
		26-50	2,464
Medium Spans	66-146	0-25	100,300
		26-50	42,436
Long Spans	147-199	0-25	24,635
		26-50	1,344
ANNUAL TOTAL			**183,286**

Bridge types developed and studied

Precast prestressed concrete structures were chosen as the focus for developing structure types and standard plans. Most bridge structures built by CDOT are precast prestressed concrete, which is greatly influenced by the robust precast industry in Denver and the lack of major steel bridge fabricators in Colorado. While cast-in-place concrete structures may be economical in certain situations, their use is currently uncommon and frequently difficult to implement due to major impacts to road clearances or rivers due to the falsework required to construct them.

Bridge widths studied

Most structures have widths between 32 feet and 94 feet, though structures much wider also are built. For the purposes of this report, some of these may simply be categorized in a fashion that is not helpful as the road may be much narrower.

Since it is impractical to analyze an infinite number of girder spacings to include in a pre-designed standard, a discrete number of spacings are necessary to make a standard. Similarly, a pre-designed standard cannot accommodate an indefinite number of bridge widths, and the widths are related to the girder spacing. A desire to accommodate the fastest type of ABC is one of the factors driving this report. Fast normally means very few pieces and stages of construction. This indicates that pre-decked construction should be accommodated, and that the widest practical widths should be used.

Several states use 16 feet as a maximum shipping width for precast sections as wider sections disrupt traffic too much. We have adopted this limit as well, and it is at the core of the section and bridge widths investigated. Predecked sections with overlapping loop connections between girders, with the loops lapping 6 inches, will have a 15.5-foot width module. This is what was chosen. Girder spacing widths were chosen to be a modular fit to the maximum width selected. To allow interior and exterior girders to be identical, exterior girders to be symmetrical, and allow for loops at the outside of exterior girders to facilitate future widening, the bridge width needs to be 12 inches wider than the module so that cast-in-place concrete can cover the loops.

Standard structure widths are expected to be 32 feet, 47.5 feet, 63 feet, 78.5 feet, and 94 feet with total live loads of 2 lanes, 2.55 lanes, 3.25 lanes, 3.9 lanes, and 4.55 lanes after adjustment for the number of lanes and multi-presence factor. Note the total live load, per code, is spread among all the girders for purposes of live-load deflection limits. Therefore, wider bridges have progressively less live-load deflection per unit width or per girder than narrower ones.

5. RECOMMENDED CRITERIA FOR STANDARD BRIDGES

The use and benefit of standard bridge plans is enhanced by carefully planning their use for current and expected future practices and needs. Perhaps most important is to ensure that the standards cover enough situations to achieve a high usage. Nearly as important is making the standards compatible with upcoming technology and practices, such as accelerated bridge construction, to ensure the standards have a long useful life. The development of new standard bridge sections will also require assessment of the applicability of current design practices and perhaps some changes to these practices

5.1. Goals to achieve maximum benefit

Four major goals were defined as important to achieve maximum bridge standard usage and life:

A. wide applicability,
B. durability,
C. flexibility for construction, and
D. low maintenance.

5.1.1 Wide applicability

First and foremost, the standards must be applicable to a substantial portion of new bridges designed and built. This wide applicability can be achieved by:

- including a broad range of span and deck width capabilities; capability for longer spans in particular reduces cost of substructure,
- using superstructures as shallow as practical; this also helps limit approach heights, approach changes, and improves vertical clearance,
- including capability for modest to moderate skews,
- including capability for modest roadway curve, though not necessarily by curving the deck or girders,
- ensuring standards are understandable/usable by contractors and engineers,
- ensuring contractors and engineers can make any needed modifications or variations to ancillary features, such as backwalls, diaphragms, forming, approach slabs, bridge rails, wingwalls, backfill, slope protection, roadway rails for pier protection, drains, and approaches,
- ensuring standards can be fabricated by a competitive number of existing local fabricators, and
- ensuring cost-effective and competitive construction by making the standards meet construction capability of most local contractors

5.1.2 Durability

Long structure life is essential for standard bridge designs because they will be constructed many times. It is essential that these bridges achieve at least a 75-year service life, with the ability to extend this life to 100 years using high performance materials such as stainless steel reinforcing.

This is not just resistance to the environment the bridge must operate in, but also resistance to functional obsolescence. Durability can be achieved by

- using robust connections between precast concrete members that emulate cast-in-place concrete construction,
- eliminating expansion or other potentially leaky joints in the deck slab,
- providing adequate reinforcing cover for the design service life,
- providing additional concrete cover in precast decks to allow grinding for fit up or traffic wear,
- designing for the weight of an overlay, even if not used,
- using common materials (not experimental),
- ensuring bridges can be widened,
- designing using widths and span lengths that can resist functional obsolescence and allowing for these widths and spans with the standards, and
- using higher live-load operating or permit vehicle capacity for interior girders for truck routes.

5.1.3 Flexibility for construction

Over time, the requirements and expectations for bridge construction have changed. Long drawn-out bridge construction with lengthy road closures and detours are no longer acceptable. Maintaining traffic and limiting traffic impacts during construction have become nearly universally critical to project success. Construction equipment and materials have also evolved; changing the limits of what is possible on the construction site. For example, larger cranes and higher capacity trailers permit the use of larger and longer precast concrete members. The bridge standards need to accommodate this evolution of construction methods and requirements. This can be achieved by

- making the bridges capable of accelerated bridge construction, preferably the fastest types of accelerated construction.
- eliminating cast-in-place deck construction by developing pre-decked girders that will allow quick construction access on structure.
- making the bridges accommodate lateral staging to maintain traffic.
- using a maximum piece width of 16 feet when possible to minimize the number of pieces and the length of joints between pieces, and thereby the onsite labor and time required.
- allowing the maximum girder shipping weight possible in Colorado as set by the current CDOT U-girders (Note that Florida is in the process of adopting spliced U girder construction and has a larger piece weight limit due to new hauling equipment capable of hauling pieces as heavy as 340 kips. Hauling equipment capabilities on the Colorado road system were the limiting factor for Colorado’s current U-girder weight limit).
- making the bridges capable of opening to traffic prior to installation of waterproofing membrane and asphalt overlay.

5.1.4 Low maintenance

The cost of maintaining a bridge over a 75 or 100-year life can be substantial, and this recurring cost reduces the CDOT's ability to make improvements throughout the transportation network. Designing and constructing bridges that reduce maintenance needs will benefit CDOT. The standards can be designed to reduce maintenance needs by

- minimizing the number of pieces and connections (less to maintain).
- eliminating joints and bearings by using integral construction.
- providing robust piers and girders capable of surviving typical truck impacts in the zone of intrusion with repairable damage (not necessarily the full CT load, which represents the impact of the engine or frame of a truck). Columns with capability of resisting impact forces of 125 kips or more have typically survived glancing blows by a heavy truck or impacts with the upper body of a truck hanging over a rigid rail. This is approximately the loading specified by other national codes for impact to girders or to the upper parts of columns.
- designing the decks for durability without using waterproofing membrane or overlays when the approach road is not surfaced in hot bituminous pavement.
- including durable bridge rails and curbs capable of surviving most vehicle impacts without needing repair and capable of long life in the splash zone.
- providing erosion-resistant backfill around wingwalls.
- making differential settlement between approach and abutment either controlled or easily repairable in the normal cycle of maintenance.
- making aesthetic enhancements as durable and maintenance free as the rest of the bridge.

5.2. Applicable design codes and procedures

Current CDOT practice for bridge design is to use the most current AASHTO LRFD Bridge Design Specifications along with the CDOT Bridge Design Manual. Both of these guides evolve over time, and the updates that are made may affect the future applicability of standard bridge plans unless these plans are updated as well. Concerns and recommendations to accommodate the design code specification and manual updates are described herein.

AASHTO LRFD Bridge Design Specifications

This code changes rapidly, occasionally making previous design efforts obsolete. Sometimes these changes are only applicable to a few states but are broadly applied by including them in the design specifications. Judgment needs to be applied regarding what changes are worthwhile and add value to the standards and the structures built using them. In particular, application of some serviceability criteria is at the discretion of the owner. At the time of this report, AASHTO is evaluating the calibration of the serviceability limits and may change these provisions without evidence that structures will be improved. AASHTO's evaluation of AASHTO LRFD code provisions usually considers the effect on current structure types but not the new structure types or on extension of practice beyond past practice (for example longer spans or larger span to depth ratios).

It will, therefore, be useful to be alert for situations in final design where the AASHTO design code seems to preclude a good solution or extension of practice without an operational reason or for which the code solution is worse than the problem. Many of these situations occur in integral construction that conflicts with code specifications implicitly based on the use of expansion joints, and the concept that more and bigger bearings and joints are better. The situation also occurs in pretensioned design that assumes that a small flexural or shear crack is somehow much worse than bigger cracks allowed in conventionally reinforced concrete sections. Another situation occurs when the code seems to require custom site-specific design, when a simpler approach may be possible. An example of this is lateral and longitudinal force-based design of substructure. A displacement-based approach can be much more appropriate when most of the forces are internal and not externally applied.

The current code is the best place to start standard design until a requirement does not make sense in the context of these standard plans.

CDOT Bridge Design Manual

This manual has not been maintained or updated to current practices and design codes. CDOT is just starting to update this manual to current design practice and design specifications. Because this update will occur over several years, it is recommended that the standard bridge plan development effort closely coordinate with the bridge design manual update effort so that

- worthwhile design manual changes are incorporated in the bridge standards.
- the changes to the Bridge Design Manual accommodate the development and use of the standard bridge plans.

Note that to be compatible with the AASHTO Manual for Bridge Evaluation, which was changed for consistency with the LRFD Code’s calibration, the bridge design manual may require an adjustment in live-load distribution factor for designs using a high order method to determine the live-load distribution.

5.3. Recommendations for design

To streamline the design effort to develop standards it is recommended that only exterior girders be designed and interior girders made identical to exterior girders. This is recommended because exterior girders typically see a higher live load distributed to them than interior girders.

There are several AASHTO LRFD code provisions needing close scrutiny for applicability when developing the standard design. These are described herein.

5.3.1. Strength II limit state and exterior girders

The Strength II limit state may result in excessive live loads distributed to exterior girders on bridges with significant shoulders when the multiple lane distribution factor governs. This issue may apply to Service II and Service III as well. This is because the LRFD distribution factors were calibrated for interior girders for a highly improbable coincident loading of two adjacent permit vehicles at the critical location, probably in traffic lanes. The probability of these vehicles occupying the shoulder should be much lower, resulting in substantially lower live-load or distribution factors for this case. If this limit state is relaxed, the exterior girders at Strength II or Service II limit states should be designed for the worst of the interior girder multiple lane distribution (to be adequate in case of a future widening), or the exterior girder single lane distribution factor.

Loads from thermogradient and volume changes

Historically, thermogradient has not been used for structure design in Colorado (except for segmental structures). It is questionable whether thermogradient needs to be applied to ductile structures for the strength limit state. Either thermogradient, when combined with other loads, will not result in cracking, in which case the use of this load for generation of moments to calculate reinforcement needs will be irrelevant, or the structure will crack, which is not prohibited under strength cases, then the moment will be relieved. We recommend that thermogradient not be required except for analysis of the construction joint at the surface of the deck at pier closures for the case of a bare deck without the future overlay.

There is a similar rationale for including uniform temperature changes in design loading for ductile structures (some column types may not be ductile). For standard bridge designs, there is typically uncertainty in column length, loads induced by thermal gradient (TU), elastic shortening (ES), creep (CR), and/or shrinkage (SH). This uncertainty, along with a desire for a robust design, encourages designers to distribute externally applied loads to the integral superstructure and then to abutments, to be supported there. The pier columns are then designed to be capable of sufficient drift or displacement under the volume change loads from ES, TU, SH, and CR without significant distress to the columns, i.e., inelastic or displacement-based design for the columns.

Skew angle

To ensure that the proposed standards are applicable for a wide range of skew angles, they should be designed for both extremes of the proposed range of skew angles using highest loading generated in the range of skew angles. Note that in some situations with large skew angles, the moments on exterior girders increase with skew, rather than decreasing as indicated by the code distribution formulas. In addition, increases in shear due to skew also may be applicable to added dead loads due to the transverse stiffness of the deck.

Horizontal shear

The strength limit state for horizontal shear may be the limiting factor for span capabilities for some of the potential standard girder sections. This code provision has changed repeatedly and may change again. It currently seems a little dysfunctional in that it allows a 20% larger maximum shear at the construction joint between the girder and deck than it does in a monolithic area of the girder or deck.

5.3.2 Service limit states

Serviceability is important to ensuring durable structures. Ignoring serviceability may lead to vibration, fatigue, sag, or excessive cracking. Careful and appropriate design for serviceability is recommended to provide durable structures that are appropriately designed for expected serviceability concerns. The two most common serviceability criteria affecting design are live-load deflection and service tensile stress.

Live-load deflection

The initial live-load deflection limit purpose is thought to be vibration control. However, other benefits (possibly unanticipated) include rideability improvements and less dead-load deflection from creep due to increased stiffness provided to control live-load deflection. This deflection limit is optional but is still followed by CDOT and has been successfully used for a long time. AASHTO is currently reviewing a change in this provision to limit loaded vehicles to the actual number and location of striped lanes when determining live-load deflection.

Many bridge types, especially those integral with their supports with integral abutments, exhibit lower deflection than a line girder analysis would indicate due to the stiffness of supports, bearings, and the interaction of the soil at abutments.

Bridges, especially shallow ones with robust bridge rails, are stiffer than assumed due to the composite action of the bridge rails with the structure. This can be of considerable benefit to shallow structures of narrow deck width. For instance, a 13-inch slab superstructure with a Type10 bridge rail is nearly 2.2 times stiffer than the slab section alone; with a 36-inch Type 7 bridge rail it is nearly eight times stiffer. This indicates that for the shallowest sections the added dead loads and live loads may deflect the structure much less than expected by standard design methods. The AASHTO LRFD code allows the added dead-load and live-load deflections to be calculated using the added stiffness of the bridge rails, which benefits the exterior girders. Using the added stiffness provided by the bridge rails may not significantly affect calculated interior girder deflections far from the bridge rails.

It is recommended that the live-load deflection limit be applied based on interior girders. In the instance where the live-load deflection on an exterior girder is greater than this, the deflection on the exterior girder will be reduced by the presence of the rail or curb, and this case will only occur for very low traffic structures. Standard structure widths are expected to be 32 feet, 47.5 feet, 63 feet, 78.5 feet, and 94 feet with total live loads for deflection of 2 lanes, 2.55 lanes, 3.25 lanes, 3.9 lanes, and 4.55 lanes. This clearly shows less live load per unit width for the wider structures.

Tensile stress (Service III)

Tensile stresses calculated in the Service III limit state often govern flexure design for prestressed concrete girders. The intent of the Service III limit state is to control cracking in prestressed concrete structures. AASHTO considers this limit optional, and its use is left to the owner’s judgment. This serviceability limit may be changed with a serviceability calibration. For instance, the 0.8 LL load factor may be changed to 1.0 in cases where detailed loss calculations are performed. The loading used may also be limited to vehicles occupying actual striped lanes rather than design lanes. Adding enough tension to meet this limit can result in excessive camber, require higher concrete strengths at strand release, or require higher f’ci in the girders. Note that the live load at the Service III limit state of 0.8HL93 is roughly equivalent to an HS 25 loading.

Prestressed structures have been designed and constructed for an HS 20 live loading in Colorado for many years with no signs of cracking, despite Colorado’s liberal overload policy. It is probable that this is partly because live loads are statistically much less on exterior girders when there are shoulders, and that prior live-load distribution factors for interior girders were very conservative. It is also possible that the 6*Sqrt (f’c) limit applied is conservative, possibly due to continued strength gain, initial over strength, and a much higher modulus of rupture, making this closer to a fatigue endurance limit for the depths of tension zone in typical girders.

Partial prestress designs that have compression under dead load plus prestress are not likely to have in-service problems with cracking since cracks will normally be closed. If they are designed to not have dead-load sag, they are also not likely to have problems with long-term geometry control, which is the main reason Colorado does not allow partial prestress design of girders. We recommend that CDOT consider allowing partial prestress girder designs for these proposed decked girder standards in lieu of Service III requirements so long as they are prestressed sufficiently to preclude sag under dead load and prestress alone. This will greatly facilitate improved camber control of these girders.

The Service III code limitations prevent the rubblization of girders caused by the accumulation of many cracks. A tensile fatigue check at the Service III limit using the same loading as Fatigue I should be considered. Due to the desire for very long life, it is recommended that the Service III limit state using the Fatigue I load be applied to the transverse deck design; this may not be necessary for deck overhangs and exterior girders when there are wide shoulders due to the low repetition of the load. It is important to keep up on AASHTO’s policy on this issue as revisions could render all standard girder designs obsolete.

Because cracking at cold joints usually occurs at a tensile stress of not much more than 3*Sqrt(f’c) it may be desirable to limit the stresses at deck continuity joints at piers at interior girders when no overlay is present and reinforcing with the potential for corrosion is used at this location. Note that research is underway in Colorado to identify surface chloride levels that can help recognize those future structures that may need extra protection. Some partial prestressing may limit stresses at this location if needed. It may be practical to place some un-bonded monostrand in the deck-girder-unit joints to add some partial stressing over the pier. Thermogradient forces may be appropriate for including in this consideration.

6. RECOMMENDED BRIDGE SUPERSTRUCTURES

New superstructure sections were developed based on the goals outlined in Section 5. All of these sections are precast concrete beams with the permanent deck part of the precast section.

6.1. Development methodology

Beam sections were sized to accommodate the bridge groupings determined in Section 4.3. Design loads were established based on current CDOT practice and analysis and modelling was completed using software listed below. Partial prestressing and stiffening by the bridge rails was not used.

Design and analysis software used

PSGLRFD—This prestressed girder design and analysis program was used for the bulk of the work in this project. This is an old proprietary program developed by the first author for rapidly prototyping simple-span, and simple-span-made-continuous, precast prestressed concrete structures. This program can batch process a large number of runs. A prior LFD version was used for design and rating by CDOT in the past. The prior version was used to run the designs required to create the current CDOT design aids for prestressed girders and to create the girders themselves. The LRFD version was created by the first author for CDOT's U-girders. This is a DOS program that does not run on WIN 7 and later operating systems due to lack of support for the programming language used. Input and output is included on the CD. A table of input and output information is in the Appendix.

LDFAC—This is an FEM program used to calculate live-load distribution factors, since most cases do not fit the simplified methods in AASHTO LRFD and those that do are sometimes excessively conservative. This program is recommended for final design. The 10 percent increase of live load for high order methods was not included and neither was the 10 percent reduction for low traffic volumes. This old program was created by NCHRP 12-26/1 and was used to verify the distribution formulas in the AASHTO LRFD code. It was used by CDOT to evaluate live-load distribution factors appropriate for U-girders. This is also a DOS program, but the first author recompiled it to run with 32- and 64-bit operating systems (still DOS). This program with documentation is included with input and output on the CD.

CONSPLICE—This is a spliced-girder design program used in this project for random verification. It is recommended for final design. This is a commercial program available from Bentley and was recently updated to AASHTO LRFD edition 6. Final design will need to accommodate the variation in the parameters that affect camber, the variability of span ratios from optimum that are to be tolerated, the variation of skews to be allowed, the location and amount of the mild reinforcing (including stirrups), and the amount of the monostrand prestressing to adjust camber and correct camber variability girder-to-girder. Input requires a few workarounds for features not implemented. An updated Library (included on the CD) was generated for this project. Input and output are voluminous. This program cannot be batch processed.

Monostrand prestressing is recommended in the girders for a number of purposes including:

A. To adjust relative camber and sweep between adjacent girders.

B. To prevent excessive girder sag. Since pretensioning needs to be limited to an amount that cannot cause excess camber when the variation in behaviour causes the girders to camber the maximum, this needs to be sufficient to add enough camber to prevent excessive sagging should the actual variation in behaviour be the opposite of that expected.

C. To control stresses at the construction joint. Monostrand may, in some cases, need to be used to control stresses at the construction joint in the top of the deck at the pier-closure pour.

D. To reduce cracking in pier and abutment caps and in girder-to-girder joints adjacent to caps. Monostrand might also be used to reduce cracking in the pier and abutment caps and the girder-to-girder deck joints near the caps, but Consplice probably will not be helpful for this analysis.

The amount of monostrand required for all these purposes is left to the final design of the standard, but is expected to be on the order of 10% of the total tensioning.

AASHTOWARE BrR (Virtis) and BrD (Opus) --- These were not used in the preparation for this report, but are recommended for rating and design checking of the girder types recommended. BrR does not seem capable of the shored pre-decking of multiple-span-made-continuous steel modules. Templates should be prepared in BrR for the rating of representative bridges that use any standards created. A final rating should be made for any bridge actually built to reflect the actual spans, skews, widths, conditions of PT applied, tensioning, and reinforcing, etc. These ratings should end up higher than the minimum targets, as the standards need to reflect worst-case design situations. Consplice is needed for the standard creation since these programs are not accurate enough to predict camber variability.

Design and analysis criteria and parameters used

Design analysis was completed using the current AASHTO LRFD Bridge Design Specifications. Specific parameters included:

- Multi-span structures use simple-made continuous design spliced over the piers.
- Modelling of continuity is approximate (a characteristic of the program used).
- Negative moment is not modelled except in Consplice runs.
- Span lengths are to centerlines of girder bearings.
- Live load - HL93 vehicle.
- Added dead loads: bridge rail – 490 lb/LF each, 36 psf for overlay between rails.
- Exterior beam design used.
- Moment distribution determined by LDFAC for the zero skew angle case. No separate distribution factor used for shear. This additional analysis is left for the final design of the worksheets.
- Precast girder weights per span limited to 238 kips.
- Concrete strength at release (f'ci) of at least 4,000 psi.
- Final Concrete strength of at least 6,000 psi at the top of deck; except more allowed in bottom of girder when required for girder tensioning. A number of sections require 6,000-psi concrete

in the deck to prevent an over reinforced condition from limiting strength. This was deemed the highest deck strength practical for achieving low bid prices using air-entrained concrete without a special design effort. A few design cases resulted in a higher f'ci required for the bottom of girder due to the large prestressing force, but still less than Colorado's prestressing practice.

- No tension allowed under prestressing and dead loading, except at pier closure.
- Horizontal and vertical shear stress limited to 1,350 psi.
- Shear strength rating greater than moment strength rating when practical.
- Final concrete strength for cast-in-place closures, joints, and top of deck concrete of 6,000 psi.
- No restriction on top tensile stress in precast girders - all sections had the top deck in compression to very near the end of the section. This can limit the required length of negative moment continuity reinforcing.
- The top 4.5 inches (minimum) of the deck concrete is air entrained or equal, modified rapid chloride < 1000 coulombs, low shrinkage, crack resistant.
- Live-load deflection limited to Span/800 (L/800) – rail stiffness contribution not used.
- Design uses the narrowest standard deck width of 32 feet. Note that for such a narrow bridge, the bridge rail weight often will be lighter, the overlay may not be present, exterior live-load (LL) distribution may be conservative (due to shoulders), and interior girder LL distribution will be conservative. Wider bridges will have slightly lower loads per girder. The design should be adequate for the interior girders of wider, more heavily trafficked roads. Unless wider girder spacing can be achieved (to lower cost) or the camber cannot be adequately controlled, the cost of more prestressing or reinforcing is small. This indicates that in some instances a somewhat less expensive structure could be custom designed using the standards represented here if a girder line can be saved by designing to the specific structure requirements of a particular bridge. In particular, designs are possible in which the exterior girder is narrower and might include the rail when shipped. Examples might have a nominal 10-foot width section for the exterior and nominal 15-foot width for the interior girders.
- Deck design should be such that a full-depth deck replacement is not needed for the design life of the structure. Designing new structures with decks that need to be replaced periodically is not cost effective in a life cycle sense, though first costs may be lower. This does not preclude grinding or overlays to correct for wear, or partial cover removal with spot removal deeper (for removal of chloride contaminated concrete) followed by a concrete overlay, though this is also likely to not reflect the best life cycle costs, but should be considered prior to a need for extensive rehabilitation.

Camber note

Camber should be within ±(L/800 +1/2 inches) at all times in service, considering variability of dead loads, prestressing force and eccentricity, shrinkage, differential shrinkage, creep, initial and final concrete strengths, girder properties, etc. Some of the longer spans require increased prestress to control sag. Many sections governed by ultimate strength require a jacking force less than 75 percent of ultimate (this also can be achieved by using mild reinforcing or un-tensioned or lightly tensioned strand for part of the reinforcing). Decreased prestress (less than Service III) with partial prestressing would ease control of upward camber for some cases.

Girder section ID and file name nomenclature

ID names = "Depth in inches" + "Girder type" of DS (Decked slab girder), DU (Decked U girder), DNX (Decked NEXT beam), or DBT (Decked BT girder) + "C" for thicker web + "Top of deck width of girder in whole feet". An abridged table of output data from the runs used to create the charts is included in Appendix A.

Input and output of all final runs and most public domain reference materials is available on CD. The information is too voluminous for inclusion in this report text.

6.2. Superstructure sections developed for standardization

Four new superstructure sections were developed to meet the requirements of Section 5. The sections were targeted to cover short, medium, and long spans as defined in Section 4.2 and 4.3 and Tables 7 and 8. Three uses were investigated:

1. Simple spans – Camber and live-load deflection control are most difficult for this use due to the reduced stiffness and the increased positive moment requiring more prestress force and hence greater camber.
2. Interior spans when splicing for live-load continuity at piers.
3. End spans when splicing for live-load continuity at piers – Shear tends to be most difficult to control in this use as the single end of fixity tends to attract composite loads at the fixed end, increasing shears.

The results for these three uses are presented in Figures 6, 7, and 8. A full tabulation of conceptual design and analysis results is included in Appendix A. Note that splicing to extend span ranges (typically near inflection points) is not included in this study because this type of design and construction is difficult to standardize due to the variability of span lengths and splicing locations. Splicing is only needed for very long spans, which are not common enough in Colorado to justify the cost of implementation. Splicing at the piers for only composite loads reduces the effect of one span on the next, increasing the flexibility of the standards.

Short spans - decked slab girder (DS)

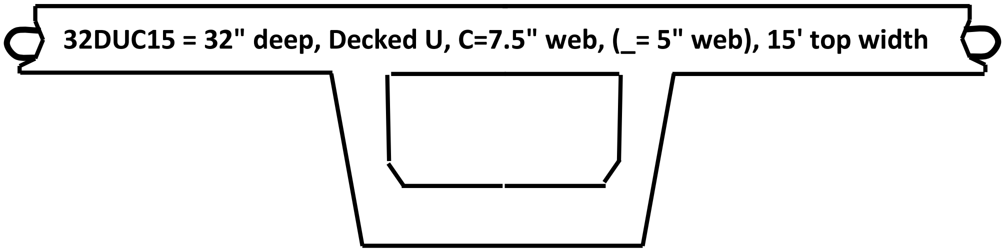
The decked slab girder is a very shallow section suitable for short spans. These girders are simple to fabricate and are well-suited to GRS-IBS systems. The girder lengths are limited by ultimate strength of the top of slab concrete and live-load deflections. Decked slab girder bridges may be expensive to construct due to the number of substructure units required by the short spans, and the volume of materials required for the deeper spans (when compared to deeper girder types). Simple spans up to 56 feet are possible with longer non-standard spans feasible if the stiffness contribution of rails is used. The most effective depths for this section range from 10 to 20 inches; depths of 10, 13, 17, and 20 inches were investigated. The most efficient section for spans lengths less than 30 feet are the 10 inch and 13 inch depths. The use of wide section widths is encouraged to minimize the number of cast-in-place joints between sections. While only a 15 foot wide section was investigated it is possible that other widths can be effective but may not see enough use to justify standardization. Figure 6-1 illustrates the decked slab girder for the 15 foot width.

Figure 6-1 Decked slab girder

Short to medium spans - decked U-girder (DU)

The decked U-girder is a shallow and efficient structure suitable for short- to medium-length spans up to 144 feet. The standard section has 5 inch webs; a thicker 7 1/2 inch web is used to increase shear capacity for longer spans or shallow sections. Figure 6-2 illustrates a 15 foot wide decked U-girder with thicker 7 ½ inch webs. Section widths can be varied; 7 feet 3 inch, 9 feet 10 inches, and 15 feet 0 inch sections were investigated for this study. Section depths from 32 inches to 75 inches were investigated and these depths are recommended as the limits for this section. If the stiffness of the bridge rails are included the span capacity of the shallow sections can be extended. The maximum span is 144 feet and the section weight may limit the useable span length. The decked U-girders are the most efficient section for span lengths from 30 feet to 96 feet. Fabrication of the U section and its void is likily to be more labor intensive than the other recommended types, and will probably increase fabrication time for this girder type compared to the other types proposed.

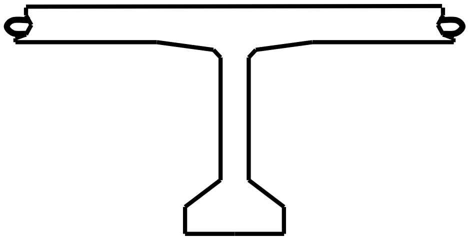
Figure 6-2 Decked U girder: top widths 15 feet 0 inch, 9 feet 10 inches, or 7 feet 3 inches



Medium to long spans - decked BT girder (DBT)

The decked BT girder was developed to extend the span capability for standard decked sections. The section is a modification of the current CDOT bulb tee girders with the top flange expanded to a full depth slab. Section depths are recommended from 48 to 69 inches, which is considered to be medium depth. Section weight limits are often encountered because of their use for longer spans; this weight limitation limits the top slab width for longer girder sections. The decked BT girder (Figure 6-3) is the most efficient section for spans above 96 feet. The maximum span capability when using live-load continuity for multi-span bridges is 195-feet. Fabrication of the DBT section is likely to be less labor and time intensive than the DU section, but the section results in deeper structures, and often will require more girder lines than the DU girders. Due to the narrower bottom flange, it is unable to carry significant construction live loads until the keyways are filled and set.

Figure 6-3 Decked BT girder: top widths 9 feet 10 inches, 7 feet 3 inches, or 4 feet 8 inches



60DBT10 = 59.5" deep Decked BT, 9'-10" top width

6.3. Other superstructure girder sections investigated

Two other sections were investigated for standard development, the decked NExt girder and decked U-girder with stretcher slab. The results of that investigation are presented herein.

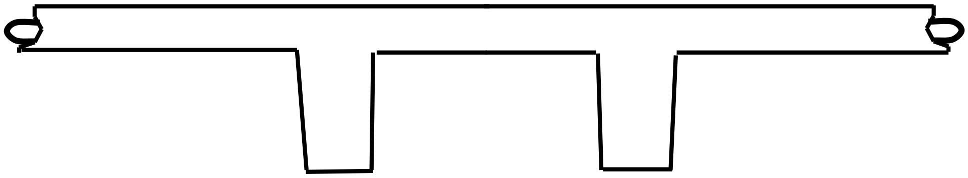
Short to medium spans for off-system use - decked NExt girder(DNX)

These sections were investigated, and the 33-inch deep section was determined to be a low-cost bridge alternative for off-system use where deck profile control is not critical. These sections are simple to fabricate and cost-effective for span lengths from 30 to 70 feet; deeper sections for longer spans will be more costly than the on-system sections. Due to difficulties controlling camber, these sections are not recommended for fully tensioned use for on-system bridges.

Benefits of this section include robust shear capacity, no flat surfaces for birds to roost, no internal voids, and less weight than the longest-span deck slabs. Downsides of this section are they are deeper than the decked slab girders and decked U-girder sections for comparable span lengths, poor aesthetics compared to slab girders or decked U girders, concentrated bearing loads increase risk of deterioration, they are not well suited to GRS-IBS due to concentrated bearing loads, fabricators in Colorado do not have beds for this section, and they are not easily suited to future implementation of capless pier design.

The section span capacity is limited by weight and live-load deflection. The maximum span is 120 feet for a 41-inch deep section when using live-load continuity for multi-span bridges. While not recommended for on-system use, the results of the conceptual design are presented in the merit vs. span charts and appendix A. (See Figure 6-4.)

Figure 6-4 Decked NExt Girder: top widths 15 feet 0 inch, 9 feet 10 inches, or 7 feet 3 inches

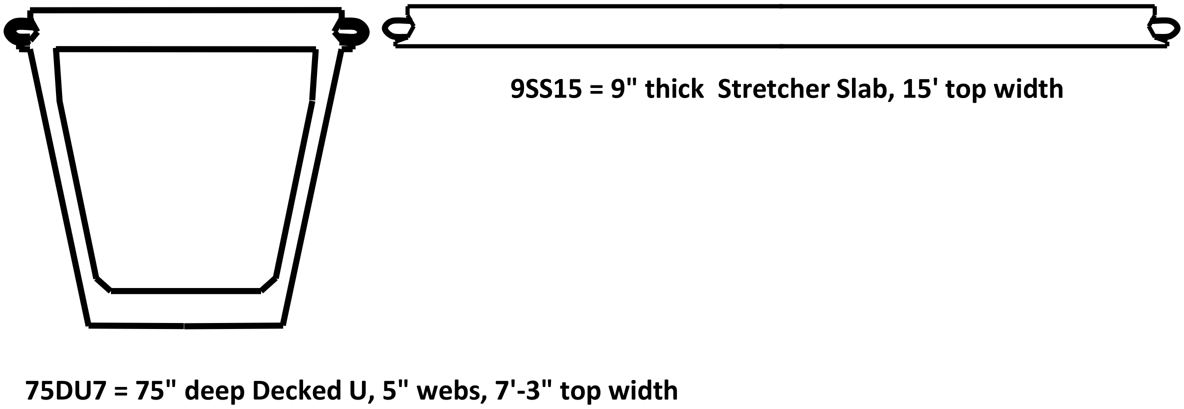


33DNX15 = 33 inches deep, Decked NExt beam, 15-foot top width

Medium spans - decked U girder with stretcher slab

This section was investigated for use in wide bridges that would benefit from wide girder spacings with a U-girder section modified from the current CDOT U-girder section. The U-girder section will be deep due to their wide spacings and the maximum span capability is limited to 121 feet due to the weight of the U-girder. The concept might be suitable for spliced design with span capabilities of about 170 ft. This system is very cost effective for a narrow range of structures, might allow for the elimination of pier and abutment caps, but does not appear to have enough applicability to justify the cost of standardization. There would be difficulty with software for design or rating as the composite deck is side by side with the pre-decked top flange of the girder, a feature that PSG allows but most other software does not. This section is not recommended for standardization and the span capabilities are not included in this report. (See Figure 6-5)

Figure 6-5 Decked U Girder with stretcher slab



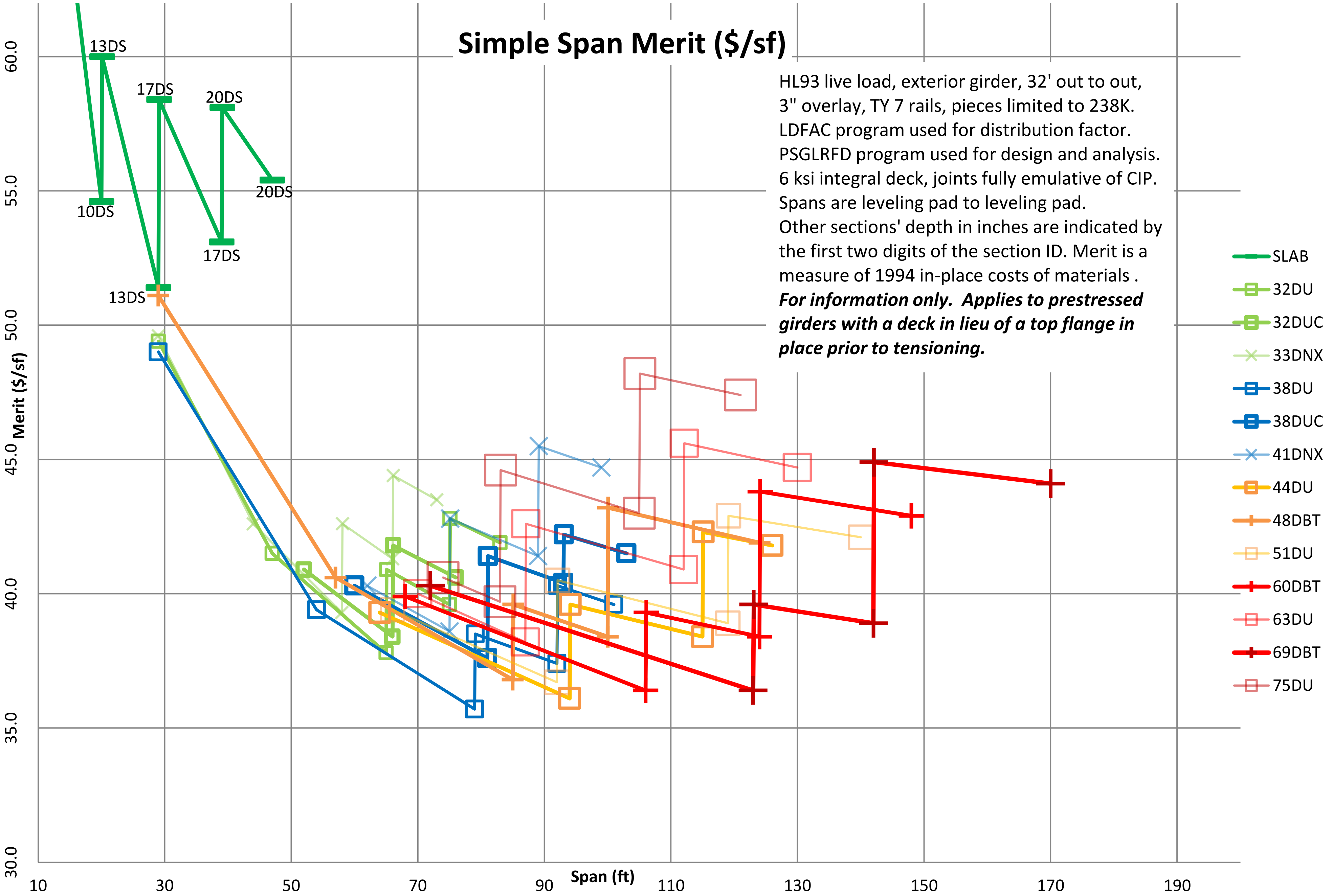
6.4. Charts of merit cost versus span capability

Charts of merit cost and span length capability were developed for the on-system superstructure sections as well as the decked NExt girder for off-system use. Figure 6-6 through

Figure 6-8 are for simple spans and interior and exterior spans of bridges made continuous for live load by splicing over piers.

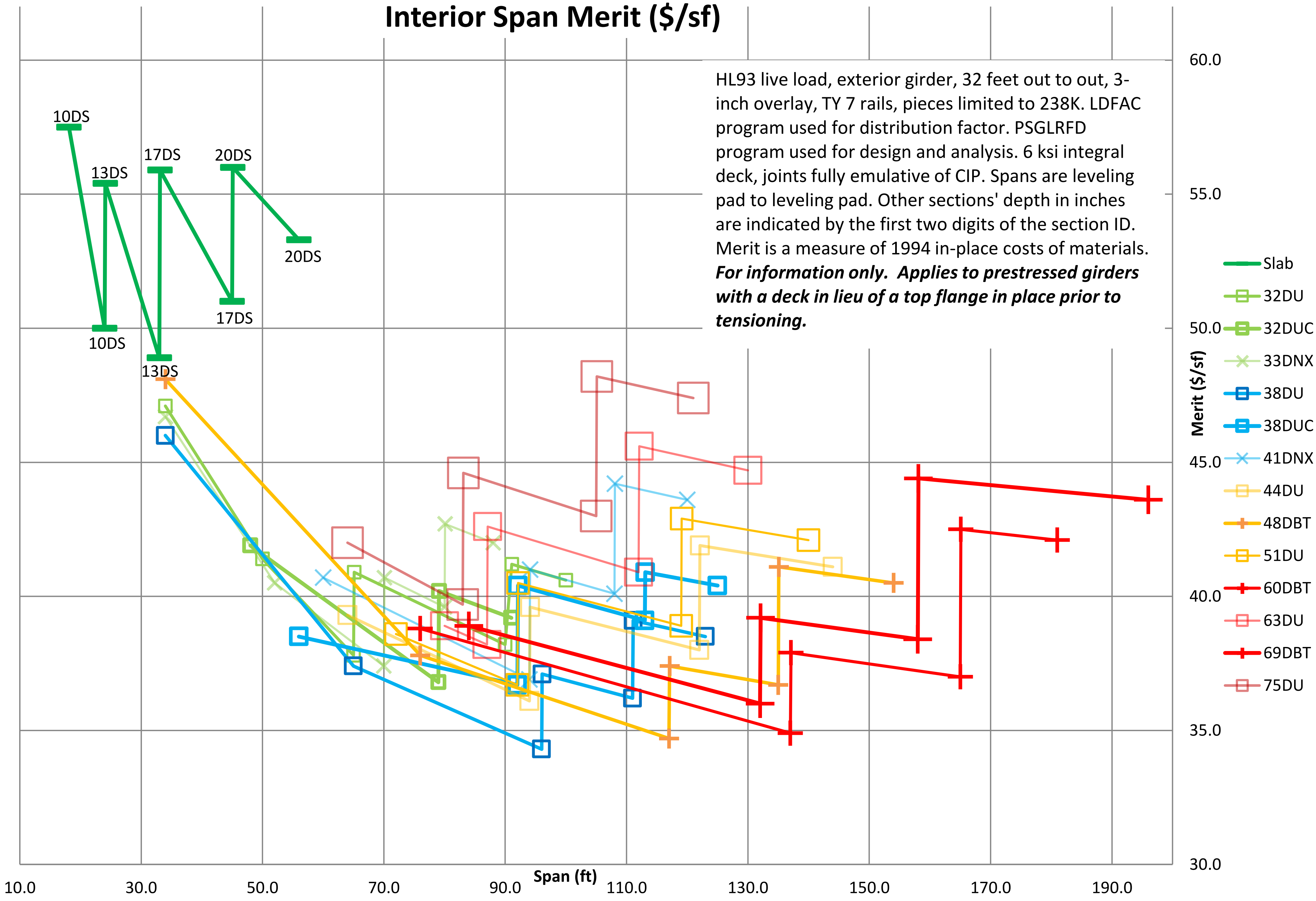
The merit cost is the estimated in-place cost of materials to construct one square foot of the bridge superstructure and supporting substructure using the section and span length noted in the chart, in 1994 dollars. These costs were developed from data from CDOT’s bid history database. The merit cost should only be used for relative comparisons and should never be used to estimate actual construction costs.

Figure 6-6 Simple span capability versus merit cost for precast prestressed concrete decked sections (for information only)



HL93 live load, exterior girder, 32' out to out, 3" overlay, TY 7 rails, pieces limited to 238K. LDFAC program used for distribution factor. PSGLRFD program used for design and analysis. 6 ksi integral deck, joints fully emulative of CIP. Spans are leveling pad to leveling pad. Other sections' depth in inches are indicated by the first two digits of the section ID. Merit is a measure of 1994 in-place costs of materials . ***For information only. Applies to prestressed girders with a deck in lieu of a top flange in place prior to tensioning.***

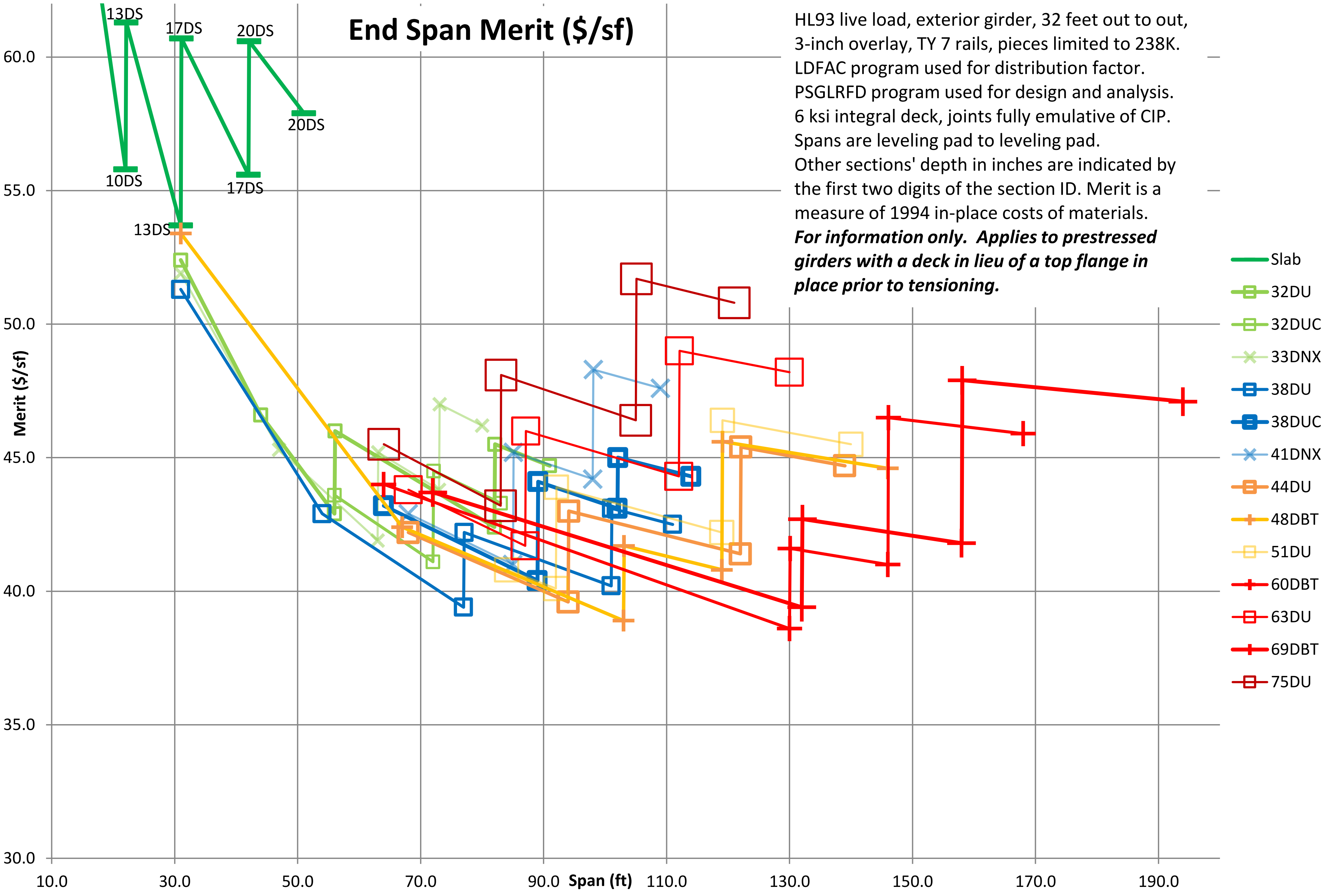
Figure 6-7 Interior span capability versus merit cost for precast prestressed concrete decked sections (for information only)



Interior Span Merit ($/sf)

HL93 live load, exterior girder, 32 feet out to out, 3-inch overlay, TY 7 rails, pieces limited to 238K. LDFAC program used for distribution factor. PSGLRFD program used for design and analysis. 6 ksi integral deck, joints fully emulative of CIP. Spans are leveling pad to leveling pad. Other sections' depth in inches are indicated by the first two digits of the section ID. Merit is a measure of 1994 in-place costs of materials. ***For information only. Applies to prestressed girders with a deck in lieu of a top flange in place prior to tensioning.***

Figure 6-8 Exterior span capability versus merit cost for precast prestressed concrete decked sections (for information only)



HL93 live load, exterior girder, 32 feet out to out, 3-inch overlay, TY 7 rails, pieces limited to 238K. LDFAC program used for distribution factor. PSGLRFD program used for design and analysis. 6 ksi integral deck, joints fully emulative of CIP. Spans are leveling pad to leveling pad. Other sections' depth in inches are indicated by the first two digits of the section ID. Merit is a measure of 1994 in-place costs of materials. ***For information only. Applies to prestressed girders with a deck in lieu of a top flange in place prior to tensioning.***

6.5. Superstructure sections considered and eliminated

Within the categories of prestressed girders and steel girders, these were considered by their ability to meet the desired criteria, and to have sufficient use to justify the effort to generate standards. These are all viable and economical structure types, but the authors considered them less able to meet all the goals of this effort compared to the fully pre-decked prestressed girders considered in depth and recommended for implementation**.**

6.5.1. Precast concrete girders

All these precast girder variations are practical and feasible types, but they are not the chosen types simply because they are not capable of the fastest ABC construction. The pre-decked option with a part thickness deck offers the second best option for implementation, and potentially could be implemented easily after the implementation of pre-decked girders with a full thickness deck as details, and to a large extent design, are the same.

Partially pre-decked prestressed girders (with a part thickness deck)

These would all be simple spans made continuous for live loads. Advantages are similar to pre-decked girders with the following differences:

- Lighter sections make shipping and erection easier, or allow longer spans to be used.
- More difficult camber control.
- Will accommodate more variable geometry.
- Cast-in-place top part of deck would be easier to achieve a good riding surface.
- Several weeks of added construction time are needed to pour and cure the top part of the deck.
- Does not allow construction traffic on deck immediately after girder setting (pre-decked BT girders do not either due to a lack of stability when live load is not applied directly over the girder before the concrete in the keyways is poured and set).

Prestressed girders with separate precast deck

These would all be simple, made continuous for live loads. Advantages are similar to pre-decked girders with the following differences:

- Lighter sections make shipping and erection easier, or allow longer spans to be used.
- More difficult camber control.
- Will accommodate more variation in geometry.
- Several weeks of added construction time are needed to place the deck.
- Requires access from below and additional crane time for panel placement.
- Less structural efficiency requiring additional depth and materials required for the girder top flange and haunch.

Prestressed girders with a conventional deck

These would all be simple, made continuous for live loads. Advantages are similar to pre-decked girders with the following differences:

- Will accommodate more variation in geometry.
- Requires more time to form deck and overhangs.
- This is the current practice. Worksheets and design aids are available, but might require updating to LRFD

6.5.2. Steel girders

The principal reason that steel girders were not investigated in greater depth is that there are no major fabricators in Colorado, so the odds of successful implementation are low. After review of the draft of this report, a limited investigation of pre-decked steel girders was made. The results of this investigation are in the CD for information only. Predecked steel girders could be implemented as an alternative worksheet, but might see little use due to the impediments listed below and in the CD.

Predecked steel girders

These would all be simple spans, made continuous for live loads. Advantages are similar to pre-decked precast girders with the following differences:

- Lighter sections make shipping and erection easier, or allow longer spans to be used.
- Less variability in camber control.
- Exacting fabrication required for diaphragms, though not many permanent ones would be required.
- Deeper sections are required.
- Wide flange (WF) sections are inexpensive, but poorly configured for efficiency in composite sections. Available heights and length of WF sections are limited and these sections may be subject to “Buy America” provisions (some sections only rolled in Canada). Welded plate girder sections can be used but tend to have high material and fabrication costs, and longer time to delivery.
- Requires cooperation between concrete deck and steel girder subcontractors. For WF girders one possible solution is to eliminate all shop fabrication and deliver directly to the contractor or pre-decking subcontractor, with only details that can be trusted to a low bid contractor with his own forces. Considerable push back could be expected from the contracting industry.
- Deck slab will be in tension unless post-tensioned or poured in a shored condition.
- Horizontal shear design method at interface is much less efficient for steel girders compared to concrete girders (a large number of studs). Concrete girder design requires enough stirrups to carry factored shear. Steel girder design requires enough studs to crush the slab or yield entire steel section, especially for shorter spans or cases where a stout shallow girder or overdesigned girder is used to control live-load deflection.

- Except for steel boxes, two girders are needed for each pre-decked piece, reducing efficiency.
- Long delivery time is common with fabricated steel.
- There are no local major structural steel fabricators.
- Steel fabricators are not used to shipping pieces as long or heavy as the precast fabricators are.
- No applicable design or rating software for steel girders constructed as simple spans and made continuous for live load.
- Entrenched industry resistant to change.

Partially pre-decked steel girders with a half thickness deck

These would all be simple spans made continuous for live load. Advantages are similar to pre-decked steel girders with the following differences:

- Lighter sections make shipping and erection easier, or allow longer spans to be used
- Can accommodate complex geometry
- Deck slab will be in tension unless prestressed longitudinally (generally very little in tension for pre-decked prestressed girders)
- Exacting fabrication required for diaphragms, though not many permanent ones would be required

Steel girders with separate precast concrete deck

These would all be simple spans made continuous for live load. Advantages are similar to pre-decked girders with the following differences:

- More diaphragms will be required than for pre-decked options.
- Lighter sections make shipping and erection easier, or allow longer spans to be used.
- Coordination is required between panel and girder fabricators.
- Can accommodate complex geometry.
- Longer erection time required for girders.
- Deck slab will be in tension unless prestressed longitudinally (generally very little for pre-decked prestressed girders).
- Long construction time to set precast deck panels, place reinforcing, and pouring and curing joints and haunches.
- Pier and abutment caps require steps at the seats and, except for steel box girders, girders need to be set vertically.

Steel girders with a conventional deck

These would all be simple spans made continuous for live load. Advantages are similar to pre-decked girders with the following differences:

- Can accommodate variable geometry.
- More diaphragms will be required than for pre-decked options.
- Longer erection time required for girders.
- Deck slab will be in tension unless prestressed longitudinally (generally very little for pre-decked prestressed girders).
- Long construction time to place reinforcing and pour and cure deck.
- This is the current practice for steel girders, but no worksheets or design aids are available.
- Pier and abutment caps require steps at the seats and, except for steel box girders, girders need to be set vertically.

7. IMPLEMENTATION COST VERSUS BENEFITS

7.1. Applicable structures for evaluating implementation cost

As developed in Section 4.3 from CDOT PONTIS data, projected yearly bridge construction data is segregated into bridge groups based on span lengths served by the recommended new standard superstructure sections.

The three superstructure sections developed for on-system bridge standardization are:

- decked slab structures (interior spans to 65 feet),
- decked U girders (interior spans to 146 feet), and
- decked BT girders (interior spans to 199 feet).

The PONTIS data indicates that about 36 new on-system bridges are built by CDOT each year. About 58 percent of these, or 21 per year, could benefit significantly from standardization because their maximum span and skew is expected to fall within the capabilities of the three recommended standard superstructure sections. Table 7-1 shows the estimated practical number of standard bridges that could be constructed each year. Some of these bridges, perhaps one-third, may be difficult to standardize fully due to geometry complexity that resists standardization. However, these bridges can partially benefit from a standardization effort by using similar standard details. Examples of geometric complexity include superelevation transition, variable skew angles, interaction between vertical or horizontal curves and skews, and multiple control lines. Bridges with concrete overlays may sidestep these complexities by allowing geometric adjustments in the overlay.

Many of the standard details developed will also be applicable to non-standard bridges, so the standardization benefits will be felt beyond the bridge groups identified.

Table 7-1 Estimated yearly CDOT on-system standard bridge construction

Group	Max. span length (feet)	Superstructure Section	Skew angle (Degrees)	No. of Standard Bridges Constructed
Short Spans	20-65	Decked slab	0-25	3
			26-50	1
Medium Spans	66-146	Decked U-girder	0-25	9
			26-50	4
Long Spans	147-199	Decked BT girder	0-25	3
			26-50	1
ANNUAL TOTAL				**21**

7.2. CDOT bridge design cost

The average cost to construct a CDOT on-system bridge is about $120 per square foot. Historically, the engineering design cost has averaged 7.5% of the construction cost, or about $9 per square foot of deck area. Field Inspection Review (FIR), or preliminary design, uses about 1/3 ($3/sf) of the total design cost. Final Office Review (FOR) design plus the Plans, Specifications, and Estimates (PS&E) design phase use the remaining 2/3 ($6/sf) of the cost.

The PONTIS data shows that CDOT constructs an average of 542,930 square feet of bridge yearly, resulting in about $4,900,000 of bridge design cost per year if the design cost is limited to $9 per square foot of area. Yearly preliminary design costs are estimated to be $1,600,000; final design is estimated to be $3,300,000. It is likely that this cost projection is low, indicating a gradual escalation of design cost over time.

The cost to produce standard designs for the 21 bridges per year targeted to standardization, less the one-third not fully practical for standardization due to geometry complexity, is estimated to be about $1,630,000 per year.

Note that the cost and difficulty to develop the standards increases with span length and skew angle as complexity of the structure section and geometry increase.

7.3. Standard plan set needs

Developing a full CDOT bridge design using only standard bridge plans is difficult to achieve, and likely will not provide enough cost savings to justify the cost of standard development. It is expected that custom general layouts (site plan with bridge), geology plans and analysis, hydraulics plans and analysis, deck elevation data, framing plans, and summaries of quantities may be needed depending on the site and bridge configuration. Much of the data for these custom sheets can be transcribed from relevant bridge standard sheets. Special bid items used can be added on a simple square-foot or linear-foot basis to reduce plan preparation effort for quantity calculation. A notes page may also be needed specifying which detail sheets are to be used with what skews, widths, and span length.

Full integration of standards is possible with the addition of partially completed plan sheet templates for general layouts, geology data, hydraulic data, deck elevations, framing plans, summary of quantities, etc. These sheets would require some data and modification for use.

Section 10 provides more detail on proposed standard bridge plan sheets.

7.4. Estimate of potential savings

When standard plan types are accepted as an appropriate choice for cost, geometry, and appearance without requiring preliminary analysis of other bridge types, and when there is no contradiction of their acceptability, at least one-third of the preliminary bridge design work cost on jobs could be saved; up to $166,000 per year. Final plan preparation savings may be twice this amount if all relevant worksheets and design aids are available, even if integrated bridge plans are not available (except for the sheets mentioned above). Integrating the bridge plans so that very little design and detailing effort is needed other than a sheet or two to connect the structural details to members, lengths, skews and details to be used would roughly double the savings in final plan production, compared to using only worksheets.

These bridge standards also could generate savings in construction. It is reasonable to expect a 10 percent savings in construction costs and another 10 percent savings in long-term life cycle costs if cost effective construction and durability enhancements are effectively incorporated in the standards. Life cycle cost benefits should be discounted in this savings assessment to a significant degree, since most of the benefits are late in the life of a structure. The current bridge worksheets and design aids have generated at least this level of savings. Preliminary design completed for this study indicates a potential of significant savings in time, labor, traffic control, materials (especially concrete), and to a lesser extent, reinforcing steel compared to current average practices. There will be reductions in crane time (though cranes may be larger on the average) and number of joints and bearings by implementing best practices (no joints or bearings when possible). Quality will also improve by using plant-produced products and materials, which are more consistent in quality and easier to reject if deficient. These savings can be much larger than plan preparation savings, especially in the case of the decked U-structures that may see the most use, based on the number and area of structures that might benefit from these standards.

Table 7-2 lists the estimated savings in design, construction, and life-cycle costs for bridges identified in the three standard span categories. The savings are proportioned among the structure types based on projected deck area construction per year. Costs of the design and detailing effort can be divided per bridge, per span, per total length, and per total deck area since the different structure types are not similar in these factors. Cost savings have not been increased to reflect that use of standard worksheets and designs may allow use of less skilled and experienced design and plan preparation labor.

Table 7-2 Estimated maximum design cost saving per year

Structure Type	FIR Cost	FIR + FOR Cost	FIR + FOR + Construction Cost	FIR + FOR + Construction Life Cycle Cost	Added saving from Partially Integrating Standard Plans
Decked Slab	$27,000	$82,000	$199,000	$316,000	$55,000
Decked U-girder	$115,000	$349,000	$1,496,000	$2,643,000	$234,000
Decked BT-girder	$24,000	$72,000	$281,000	$490,000	$49,000
TOTAL	**$166,000**	**$503,000**	**$1,976,000**	**$3,449,000**	**$338,000**

FIR cost saving per year

This is the expected bridge program cost savings per year for all the structures of the bridge type it might apply to for design and plan preparation taken only through the Selection Report and FIR plan preparation. This assumes that the standard types are accepted as the only type that needs to be investigated when they are applicable. Relatively little needs to be complete in the implementation except design work sufficient to determine the cost and size of sections needed (as far as plan sheets) to gain this savings, but design aids such as the charts or tabulation of design capabilities would be needed as well as the worksheet defining the cross sections. It might be difficult for plan preparation to proceed beyond this point unless at least the framework of the girder and pier worksheets was complete, as these sections are not included in the current worksheets.

FIR + FOR cost saving per year

This is the expected bridge program cost savings per year for all the structures of the bridge type it might apply to for design and plan preparation taken from the beginning of type selection through the FOR. This assumes all needed worksheets are available for the type selected, and that no structural design or detailing of the actual structural elements is therefore required. Most of the saving is the plan preparation and design that will not be required because it is included in the new worksheets. All the plan worksheets for the bridge type need to be fully implemented for this saving to be valid, except for work to integrate the plan sheets together (would be handled by current methods). Note the critical path for plan preparation between the FIR and FOR is often controlled by the time to complete the bridge designs, prepare the final bridge plans, and calculate the bridge bid quantities. Often the QA/QC of the plans also adds to this time frame.

FIR + FOR + construction cost saving per year

This is the expected bridge program cost savings per year for all the structures of the bridge type it might apply to for design and plan preparation and construction taken from the beginning of type selection through Construction. This assumes all needed worksheets are available for the bridge type selected and that no structural design or detailing of the actual structural elements is required. Experience suggests there will be a considerable saving in the construction costs due to the selection of structures that have standardized details and construction cost and time for a given bridge size will be minimized. The construction cost savings is estimated to be 10% of the construction cost based on the savings experienced by prior worksheet efforts to standardize design. Savings in approach construction costs due to the thinner sections has not been included.

FIR + FOR + construction + life cycle cost saving per year

This is the expected bridge program cost saving per year for all the structures of the bridge type it might apply to for design, plan preparation, construction, maintenance, and longer life taken from the beginning of type selection through eventual structure replacement. This assumes all needed worksheets are available for the bridge type selected, and that no structural design or detailing of the actual structural elements is required. The construction cost saving is estimated to be 10% of the construction cost based on the savings experienced by prior worksheet efforts to standardize design; the saving from reduced maintenance and longer life is also estimated to be 10% of the construction cost. Saving in approach construction cost, due to the thinner sections, has not been included.

Additional savings from partial integration of plans cost saving per year

This is the expected additional bridge program cost saving per year for all the structures of the bridge type it might apply to for plan preparation of a standardized sheet(s) to identify the features, sections, member lengths and locations, skews, etc. to be used, and including all the required design information on the substructure and girder worksheets. This should include a simplification of quantities in some fashion, by changes in bid items, or some sort of automation of quantity calculations from the information in the work sheet. This saving consists entirely of savings in detailing time and effort. Note this integration would also save time between the FIR and FOR.

7.5. Estimated implementation cost

The cost to implement each major option to the worksheet level for 0 to 25-degree skew angles is approximately the cost to design and prepare plans for three bridges of the standard type, and the additional cost to expand the design and details to accommodate larger skews is about the same as the cost to design and prepare plans for one more bridge of the standard type. The cost to integrate these worksheets into a standard set of plans (standardized bridge plan set) is about the cost to prepare two sets of plans per standard bridge type depending on the level of automation. Extending the decked BT-girders to accommodate larger skews may not be cost effective due to a small number of structures and small deck area of this type expected per year (they tend to be narrower deck widths). It is assumed that all structure standards will include moderate skew, as the zero-skew condition is just a subset of the low-skew situation.

Experience suggests that it is better to create standards as part of the design of an actual structure design project. Integrating the use and design keeps everything on track and assures at least partial review and checking to a more realistic situation. Nearly every successful standard CDOT has created has been through an actual bridge design (prototype) that is sufficiently generic without uncommon site-specific requirements. The implementation costs listed in Table 7-3 are the additional development costs beyond the usual design and detailing cost of the prototype structure. It is recommended that the prototype structure have multiple spans and be at least moderately skewed.

Concepts for substructure standardization are not as advanced as the superstructure concepts. This causes a degree of uncertainty in the implementation costs so the implementation costs are much fuzzier for the substructure standardization.

The implementation effort required is not refined enough to reflect differences between in-house and consultant forces, but does assume forces skilled at developing new worksheets and structure types.

Table 7-3 Estimated superstructure standard implementation costs

Type	Worksheet Level	Incl. Larger Skews	Incl. Integrated Partial Plans	Yearly maintenance
Decked Slab	$255,000	$330,000	$576,000	$29,000
Predecked U	$345,000	$468,000	$822,000	$41,000
Predecked BT	$417,000	$525,000	$912,000	$46,000

7.6. Payback time

Few standard plan sets have a benefit beyond about 20 years without major updates or changes. It is estimated that standards will incur costs of maintenance roughly equal to the costs of creation over this period of 20 years. Early superstructure implementation is recommended in the following order:

1. Decked slab structures to the worksheet level for moderate skews (because it is easy and will help sort out presentation and plan organization issues).
2. Decked U-girders to the worksheet level for moderate skews.
3. Extend skew angle capability for decked slab structures.
4. Extend skew angle capacity for decked U-girders.

An estimate of payback time based on only implementation cost divided by plan preparation savings less maintenance costs of the standards is shown in Table 7-4.

Table 7-4 Estimated time to recoup implementation costs

Standard Plans	Years to recoup implementation cost
Decked slab girder – worksheets 0-25° skew	5
Decked U-girder – worksheets 0-25° skew	2
Decked slab girder – extend worksheets to 50° skew	7
Decked U-girder – extend worksheets to 50° skew	2
Decked BT-girder – worksheets 0-25° skew	13
Decked BT-girder – extend worksheets to 25°-50° skew	7
Integration of decked slab girders	2
Integration of decked U- girders	1
Integration of decked BT-girders	4

Generally, payback times of approximately three years are considered “low-hanging fruit” for return on investment and generally will be cost effective even if subject to moderate implementation overruns or flagging implementation results. Payback times up to seven years are considered acceptable, and payback times of 14 years and beyond are not cost effective.

Including potential construction cost savings or life cycle savings would make all of these items “low-hanging fruit” simply because standards can be a good way to introduce and enforce best available practice. However, construction savings may take some time to realize and are uncertain. While life cycle savings are more certain, they should be discounted due to the long time to achieve payback. Decked U-girders fare well simply because they have a wider range of applicability by number of bridges, area, length, and spans relative to either decked slabs or decked BT-girders. These factors entered into both the average plan preparation costs and the potential savings used for each type.

7.7. How this proposal fits with Section 5.1 goals

The primary factors are as follows:

Wide applicability is achieved by shallow depth, a large range of span capabilities, accommodating fairly long bridges (up to 700-800 ft. with current proven CDOT integral bridge practice), accommodating a range of span lengths rather than specific span lengths, accommodating a range of skews rather than specific skews, accommodating a range of number of spans in a bridge rather than just one, two or three spans, and accommodating a number of different structure widths.

Durability is achieved by integral construction and plant production of most of the bridge. This can be enhanced by the appropriate choice of materials in the final details, for example sealers, membranes, or corrosion resistant reinforcing as appropriate to the structure’s environment as may be determined by ongoing surface chloride research.

Flexibility for construction is achieved by ABC oriented precast pieces that require little forming and are generally self stable once placed, and structure schemes that allow for staging construction without falsework.

Low maintenance is achieved mostly by the elimination of joints and bearings, and sufficient cover to allow for grinding of the deck. Appropriate choice of materials can be helpful here too.

7.8. Other worksheet needs

Some ancillary details will need to be worked out as well, but are not included in implementation costs. These details include changes to bridge rails and curbs to make them ABC compatible, possible changes to the Colorado M-Standards for pier protection to address the 54-inch TL5 rails and trucks bypassing or riding over approach rails, and possibly a sheet of low-cost maintainable highly aesthetic features. These things should be accomplished regardless of any standard bridge plan efforts but are essential to the standard plan implementation. Integrating worksheets into partial plan sets does not seem to have substantial benefit on FIR costs, construction costs, or life cycle costs, but might reduce the time and costs to produce plans after FIR. Since worksheets will reflect spans, etc., it may be practical to add quantities to the worksheets to aid in cost estimating at all levels (as is done on the current culvert and bridge rail sheets).

Note that worksheet level only includes creating or updating worksheets specific to and for a standard bridge plan effort for the particular types, not the full spectrum of CDOT Bridge's worksheets, which may need work.

7.9. Comparison to other DOT efforts

As a quick check on implementation costs, the Texas Department of Transportation has about 1,200 sheets of standard bridge plans that are used for perhaps 20 percent of new bridges built in Texas, according to the current State Bridge Engineer. At 40 to 80 hours per sheet, this represents perhaps 72,000 man-hours of effort. At $120/man-hour, this is potentially more than $8 million to implement and $400,000 per year to maintain. This system works for Texas because their program is perhaps eight times the size of Colorado's bridge program. It would not add benefit to prepare as many plan sheets in Colorado. Specific numbers of spans and lengths and specific skews, rather than ranges, restricts applicability when the standard results in a poor match to the specifics of a site. However, this approach of allowing for a range of spans and skews rather than discrete values requires more effort per sheet to broaden each sheet's applicability. This broader applicability to more different span lengths, a wider range of bridge widths, more variable skews, and a greater number of spans and span ratios will allow a Colorado standard bridge effort to apply to a larger portion of the new bridges built in the state.

The Massachusetts Department of Transportation has spent perhaps $500,000 on a multi-year effort to develop letter-size detail sheets of standard details for inclusion in plans. It is up to a designer or detailer to integrate these into plan sheets. This may be useful for the host of typical sections we may have, as an aid for report writing, and general layout creation. Volume 3 of the Massachusetts Bridge Design Manual, which will include girders, has not been completed yet.

Pennsylvania DOT's BRADD software is purported to have more than 750,000 lines of code. It can complete a wide range of single-span structure types, but the system is cumbersome to maintain, took several decades to implement, and the structure types supported are not currently capable of meeting SHRP T-19 (Design Guide for Bridges for Service Life) recommendations, goals, and ABC goals. It’s implementation and maintenance costs are similar to Texas’s standard plans. The limitations of only providing for single span bridges would severely restrict any benefit in Colorado.

The Wisconsin DOT’s ongoing automated design-to-plans system is perhaps more effective, but it required a champion (the current Wisconsin Bridge Engineer) and two decades to get to the current capability. Loss of the expert champion for a project like this can be a fatal flaw. Similarly, any lesser effort still requires continuous (but not necessarily full time) effort by a champion for ongoing implementation, training, and maintenance. If similar efforts will become standard in the industry, the need for a champion will fade.

The large effort required to implement and maintain automated systems indicates that a much larger usage base is needed than Colorado can provide. A multi-state effort with common plan formats, details, and design policies is called for, much like the AASHTO Bridgeware Virtis or Opus projects, though multi-state regions with common bridge needs should have enough need to justify the implementation cost.

7.10. Other extensions of the concept excluded

A number of concepts with promise were investigated to a degree, but are not part of the proposed implementation. These concepts include capless piers, stretcher slabs to widen U-girder spacing, varying decked girder widths to accommodate differing live-load and composite dead-load distribution between interior and exterior girders, girders decked only to the extent needed to serve as stay-in-place formwork, higher live-load capacity for designated truck corridors, designs to accommodate light rail or commuter rail, structure types applicable mostly to off-system structures, and fully tensioned closures at piers. All these concepts are useful and could be economically implemented as a standard as part of a large project implementing at least several structures of one of these types. Inclusion at this point would only multiply the number of options to be dealt with and would hinder implementation.

8. SUBSTRUCTURE

In order to provide bridges meeting the requirements for durability, economy, and capability of accelerated construction, the basic design behaviour and configuration of substructure units must be defined. Some conceptual ideas presented herein can be expanded upon approval of the proposed superstructure standards. More comprehensive assessment of potential substructure standards cannot be completed without finalizing the direction for development of the superstructure standards.

8.1. Recommendations for integral behavior

Provide fully integral construction: Standard practice starts with CDOT current integral-length limits while allowing for future expansion of length limits as the practice of designing integral structures improves. The capability of a 0 to 4 inch expansion joint at the end of approach slabs may limit the expansion length limit, although using higher movement expansion joints can remove this limitation. For example, one structure in service in Colorado has finger joints at this location to allow an integral length of more than 1,000 feet.

Where columns are asymmetrical, (HP shapes) and when skew is small, orient piles so that strong-axis bending resists longitudinal motion, and orient the strong axis to resist transverse motion when the skew is large. Large skews on long structures also may require pile battering transverse to the structure axis to prevent structure twisting.

Design should assume a plastic hinge at top and at point of fixity of each pier shaft with plastic behavior at full factored load (hinged at bottom and top (K = 1)).

8.2. Recommendations for pier and abutment standards

The superstructure standards will ultimately have tabular information including reactions on the substructure units. The standards are recommended to:

Spread foundations

- Prevent the use of spread foundations for permanent supports where there is a scour risk in the 500-year flood event. Spread foundations use should also be prevented at abutments of multi-span bridges where the residual settlement is expected to exceed 0.005 of the adjacent span length.
- Limit the peak ultimate soil bearing pressure to six TSF and provide a means to reduce bearing pressure to less than three times the adjacent surcharge at edges of soil-bearing area (Limitation may be achieved by inserting a thin tapered layer of geofoam under the top layer of filter material, or by applying load eccentrically on a spread footer).

Columns, shafts, and piles

Figure 8-1 and Figure 8-2 illustrate the following points:

- Interface with girder standard plan tabular information that will provide factored axial load (Pu) capacity required for each column or pile.

- Include a column selection table with the maximum Pu (axial capacity) and maximum unsupported length for the various column sections.
- Use Grade 50 steel compact shafts such as HP shapes or square or round steel tubes filled with 6-ksi concrete.
- Columns should be capable of resisting 125K vehicle collision (CT) load or more at any location between the ground and 14 feet above the ground (incidental impact in zone of intrusion). Identify any shafts capable of resisting the 600K CT load in the table.
- Do not include full LRFD impact loads in column design. On standard plan note requirement for shafts adjacent to a roadway that do not meet the CT load strength, or either code minimum offset from lane to column, or provision for a concrete barrier protecting the shaft. Satisfy railroad impact provisions by providing their required track to column offset.
- Ensure KL/r from seat to point of fixity < 114 (assumed as locations of plastic hinges)
- Distribute lateral loads based on relative stiffness, i.e., most external transverse and longitudinal loads go to abutments.
- Limit factored axial load to (0.33 x Fy x As) for H piles or the greater of 0.4 x (Ac x f'c + Fy x As) or 0.6 x FyAs to control driving stresses and minimize the reduction of flexural strength and stiffness from axial load, allowing a high drift ratio and high lateral resistance before distress.
- Allow shafts grouted into holes drilled into the ground, or shafts driven into the ground, or shafts grouted into sockets in precast footings at piers (detail not proposed for incorporation in standard due to limited application)
- Note that AASHTO is considering changes to allow greater design capacity of round filled tubes. Should this happen, this increased flexural and axial capacity might be utilized in the case of shafts concreted into holes drilled into the ground. Much research has been published in the last year, and AASHTO voted on some LRFD modifications to facilitate this.
- Provide increased durability by attaching a sacrificial zinc anode 1.5 feet below the finished ground line
- Provide column spacing to fit the structure width module (15.5-foot module + 1-foot tot for bridge edges, i.e., 32-foot wide structure has two columns spaced at 15.5/Cos (skew), the 47.5-feet-wide structure has three columns at the same spacing.

Figure 8-1 Elevation – recommended pier or abutment standard precise cap detail

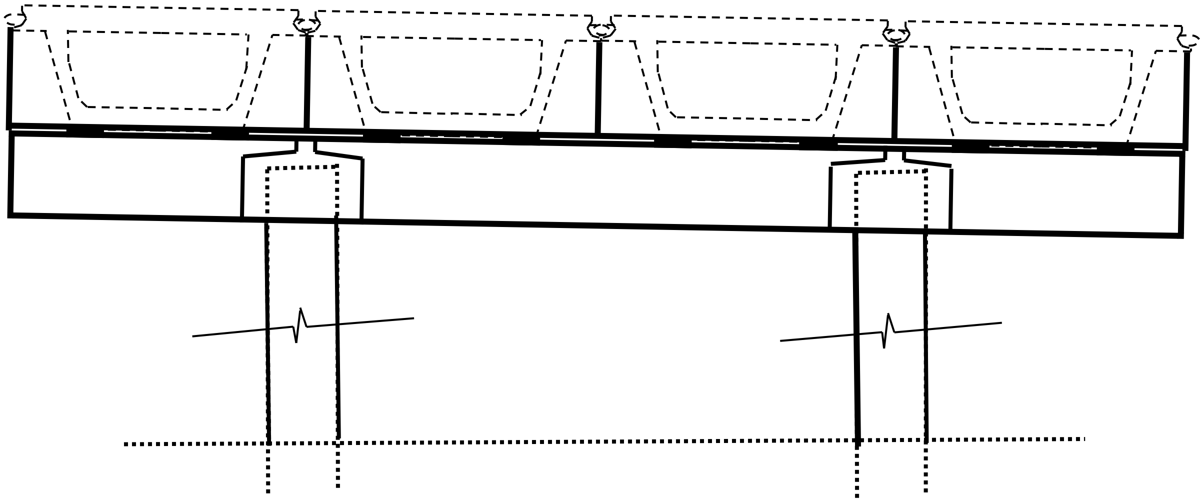
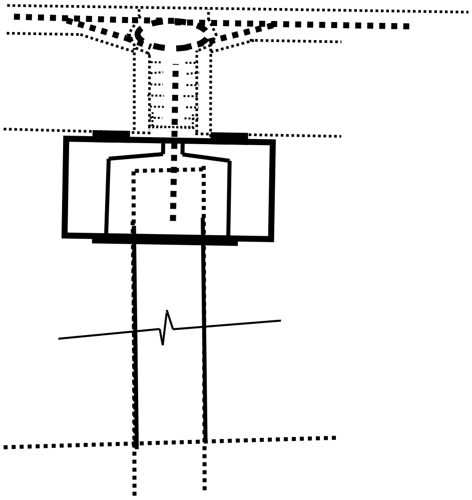


Figure 8-2 Section – recommended pier standard precast cap detail



Caps for piers and abutments

- Include a table of standard designs based on factored girder reaction per 15.5-foot unit bridge width.
- Tabulate dimensions and reinforcing requirements with column/shaft data for each shaft size, with notes on applicable minimum substructure depth to apparent fixity.
- Allow twice as many piles to be used (1 per 7.75 feet of bridge width, with half the Pu per pile) at the discretion of the engineer
- Provide a corrugated socket for the top of the shaft.
- Slope to match the grade and cross slope of the bridge.
- Be hinged at the seat.

- Be designed as composite between lower cap and upper diaphragm/span closure.
- Include a row of dowels and a hinge with the dowels anchored in closure concrete.

8.3. Recommendations for use of approach slabs

The use of approach slabs can provide some flexibility when the approach is expected to settle relative to the abutment. Approach slabs also provide a means to add expansion joints to the ends of integral structures. The following guidelines are recommended for the use of approach slabs.

If thermal motions require an expansion joint:

- For foundations on continuous spread foundations immediately under the integral abutment the abutment depth (H), noted below may be increased by the width of the spread foundation to reflect the additional flexibility of the soil under the abutment.
- No approach slab is necessary when abutments are a distance from the point of fixity (Lt) less than 11H.
- For concrete bridges with asphalt approaches, abutments with Lt less than 44H may not require approach slabs with joints due to uncertainty of actual motions. If possible, install an approach slab on a sleeper, and wait a few years and see if there is approach pavement faulting. If there is faulting convert one end of the approach slab to a condition with an expansion joint. If there is significant differential settlement of the approach with respect to the abutment continuing to occur, this joint should be at the abutment end of the approach slab, to allow for corrections of approach grades as a part of routine approach pavement maintenance.
- Provide approach slabs with expansion joints for abutments of steel bridges with Lt greater than 11H.
- Provide approach slabs with expansion joints for abutments of concrete bridges with Lt greater than 44H.

If differential settlements require an approach slab:

- If there is no significant grade change at approach (< 3 feet), settlement should not be significant (should be less than 0.5 inch) unless approach soil is very poor.
- If expected residual settlement is greater than 0.5 inch, an approach slab should be used if the approach pavement is concrete. Residual settlement should in all cases be assumed to be at least one-sixth of the predicted ultimate settlement after any surcharging or construction timing to reduce settlements. Approach slab lengths should be at least five times the speed (mph) times the amount of residual settlement.
- With asphalt approach pavement, do not use approach slabs for settlement mitigation alone. Approach settlement differentials can be more effectively corrected by routine asphalt pavement restoration. If both settlement mitigation and thermal motion mitigation are required (Lt > 11H), an approach slab with the joint at the abutment end is required.

8.4. Recommendations for abutment backfill and wingwalls

If an expansion joint is required at the end of an approach slab, provide MSE backfill wrapped 2-inches clear from the back of the abutment. For wingwalls, backfill the tip and front sides of wingwalls using flowfill, except for a top 4 inch layer of topsoil. For GRS-IBC construction with girders placed directly on soil, provide a 30-inch depth of Class A filter material below girders wrapped in filter cloth in 10-inch maximum layers.

Construct wingwalls integral with the abutment endwall/diaphragm. Orient wingwalls for minimum length by bisecting the angle between the road and abutment. Wrap-around MSE walls can be used as wingwalls, but they require more time to install compared to precast concrete wingwalls. Do not use excessively long wingwalls. If necessary, use short to modest length wingwalls and continue the length with a separate retaining wall not connected to the bridge.

Reinforced concrete paving is commonly used for slope protection at abutments. To facilitate accelerated construction and make slope protection construction less weather sensitive consider other slope paving materials such as concrete pavers, slope mattresses, or even stepped MSE walls.

9. MISCELLANEOUS DETAILS

9.1. Type 10 bridge rail curb shell

To speed construction, a stay-in-place formwork of Fiber Reinforced Cementitious Composite (FRCC) could be used and filled with concrete when girder-to-girder joints between the precast decked sections are completed and could even be attached prior to shipping. Besides speeding construction, no formwork would need to be removed, saving a construction step and reducing traffic impacts. An outer shell of FRCC might be more durable and crack resistant than regular cast in place concrete for the curbs.

9.2. Type 7 bridge rail shell

To speed construction, a stay-in-place formwork of FRCC could be used and filled with concrete when girder-to-girder joints between the precast decked sections are completed and could even be attached prior to shipping. Besides speeding construction, no formwork would need to be removed, saving a construction step and reducing traffic impacts. An outer shell of FRCC might be more durable and crack resistant than regular CIP concrete for these rails.

9.3. TL5 pier protection

The vehicle collision force (CT) loading is not always practical for pile bents or small piers, as the 600K CT load requires a large column to resist it. The large columns are often very stiff, precluding integral construction if too short in length. The code allows the use of a 54-inch TL5 traffic rail in lieu of the CT design load. Several crash-tested rails are available, and the appropriate sheets of the M-Standards could be modified to include one of these shapes. Alternatively, the shorter Type 7 traffic rail could be used with provision to keep trucks from either getting behind the rail and hitting columns from the back, or mounting the rail and sliding along it into the pier. The column would then only be subject to the much smaller CT load from the parts of the truck leaning over the rail into the zone of intrusion. Because this is not a provision of AASHTO LRFD, CDOT would need to choose to accept the CT load reduction.

Many states are struggling with 54-inch TL5 rail pier protection or 600K pier collision loads, their costs, and effect on ABC.

10. PROPOSED STANDARD BRIDGE DRAWINGS

10.1. Description and goals

The essence of creating standard bridges is to eliminate customization of sheets to the greatest extent possible. Reduce information to the essential to describe the product required, while still not requiring design effort on the part of the contractor, besides his usual means and methods. This includes leaving erection method design to the contractor, since it tends to be site specific. If information is duplicated elsewhere in the plans, it should not be included in the bridge standard plans. Duplication of information should be eliminated within the bridge plans, with the possible exception of bridge geometry input data, which is often needed for proper checking and to track if the roadway design has changed since the bridge plans were assembled.

Sheets marked with an asterisk (*) may be optional in the development of a system of standard drawings for precast bridges and may be developed as a template only.

10.2. General notes and summary of quantities*

In many ways, this sheet will be similar to the current worksheet however, the materials, bid items, and notes will be different. A different template or example sheet will also be helpful. For the bid items, some could be the same: rails, asphalt, membrane, expansion joints, backfill. Some others, most appropriately measured and paid by square foot (SF) such as the slab girders in various depths, approach slabs, and wingwalls, should be different. Others, such as the decked U- and BT-girders, should have items based on their nominal width and paid by linear foot (LF). Caps and shafts should have items based on load capacity groupings and paid by LF. End diaphragms/stay-in-place end forms, and grout to fill joints between girders and make continuity closures should be included in the girder work (or paid by LF). Concrete to fill shafts and concrete shafts into drilled holes in the ground should be included in the price of the shaft or pile. Bare-deck slab girders made continuous might benefit from some continuity unbonded tensioning in the joints between slab girders to keep any cracking at the deck top at the construction joint tight when there is no overlay. This can be either paid on the usual basis or included in the work.

10.3. General layout*

This sheet will include similar information to current general layout sheets. In many cases, geology and hydraulics information could be included here unless there is too much information to show on the sheet. Large structures may require more than one sheet to maintain a reasonable scale.

Most data on this sheet duplicates data in other areas of typical plans; therefore, for the most simple structures, those with simple geometry, no utilities, no construction staging, no fences, or walks, no special hydraulic features, it might be possible to treat them like standard box culverts are treated, with site data presented on the roadway plan and profile sheets.

10.4. Engineering geology*

This sheet exists to show the juxtaposition of the test hole data to the structure. Historically, the test hole data was shown on general layouts, but in the last two decades was moved to its own sheet. If the general layout sheets are not too cluttered than it may be possible to return the test hole data to the general elevation sheet.

For GRS-IBS spread-foundation style structures, there may be few test holes whose precise positioning is not critical, so the engineering geology information could be presented on the roadway plan and profile sheets.

For structures with deep foundations, or foundations on rock, there is usually at least one test hole per substructure unit, and juxtaposition of the holes and materials to the bridge is critical, including for determining quantities and pier shaft lengths. The scale of roadway plan and profile sheets is frequently too small to accommodate either the number of test holes or the precision of plan and elevation locations.

10.5. Construction layout*

This sheet may not be needed if the general layout includes information on rail types, overlay, walks, fences, and utilities. This sheet is also not needed if there is another sheet, such as the prefabricated parts and stick figure that dimensions skews, lengths along the girders and caps, and identifies all the members, including wingwalls.

10.6. Footing and piling layout*

Including this sheet will be a judgment call. If there are underground utilities or obstructions near the foundations, a custom footing and piling layout should be included. Design data normally is included in the geology report.

10.7. Prefabricated parts list and stick figure

This sheet ties the standards for the pieces together into a standard bridge package, but maintains some flexibility for span lengths and skews. This sheet contains the basic configuration of the structure showing members as a stick (line element), with an ID more fully described on the standard details for each prefabricated member and showing its orientation by skew, station, member type, and length. For longer and wider bridges, this might require multiple sheets. This sheet will require at least a few notes.

The CDOT geometry program has a utility “stick” that can generate at least the plan view from the bridge geometry program’s output. It might be possible to modify the “stick” to include the identifier labels and member lengths.

A checklist of optional items—like aesthetic enhancements, reinforcing type, coating and color, overlay type, rail type, fence type, and drains—could be included on this sheet.

It remains unclear if just using an identifier to the appropriate detail with length will be sufficient, or whether there needs to be a tabulation of all the pieces. Providing the tabulation would increase the effort to complete this sheet considerably, but might offer the possibility of customizing items like the required embedment lengths of the shaft members in various soils encountered. It is possible that this can be covered by notes on the substructure standard sheets.

An optional typical section sheet should be considered to identify elements like sealer, surfacing, rail types, fences on the structure, lane and shoulder widths (usually shown in roadway sheets), as well as to illustrate the typical section. Since this sheet does not need to show skew, crown, cross slope, etc., it may be practical to make a MicroStation kit sheet file with layers for all these things that can be turned on (layer for each of the widths and rail combinations, and overlay or not, layer for each girder type). Depending on the completeness of the checklist, this feature may be unnecessary, except that this might be useful for selection reports, as might the stick figure.

10.8. Girder standard sheets

Each girder type requires detail sheets. In many ways, these will be similar to existing girder worksheets and will contain:

- A detailed section showing reinforcing.
- Notes, similar to those used on the current girder worksheets, with perhaps a few related to timing and amount of unbounded tensioning, and to the top of deck concrete criteria.
- A basic plan view showing deck steel orientation and how it varies along length and showing location of bar projections for rails. Possibly other details can be shown here.
- An elevation that shows schematic strand paths and how stirrups vary along the length, bars and strand projections into closures at substructure.
- Dimensioned sections of the spectrum of girder sizes for the girder type, probably located on a second sheet (potentially listing properties). There may be two widths and four depths for the decked slab section, three widths with three depths and two web thicknesses for the decked U-sections, and three widths and three depths for the decked BT-sections. For custom designs (not those intended for standard bridges), a few deeper decked U- and BT-sections might be helpful. If shipping weight limits should relax in the future or if a structure needed to carry additional loads or deflect less, these sections could be used.
- A tabulation of designs, containing for each girder section the section ID, simple, interior or end span, length, dimensions, prestressing data, expected deflections, etc., as needed to complete the girder design. This may take several sheets, since there is a lot of data needed to define the girder design, with several depths and widths for each girder type and probably a minimum of two and possibly several more lengths for each of these such that the design data can be interpolated accurately for the actual piece lengths. A great amount of design, but little detailing, goes into the creation of these tables.
- Space for a tabulation to be filled in by the designer, either to do any interpolation needed, or more likely to use the sheet as the current worksheets are used, for a custom design. Plan sets that use this fill-in tabulation of girders do not need to include sheets with the tabulations of designs for the standard girders.

Since format of the sheets, details, notes, etc., will take some effort to perfect, it is best if a structure type's girder sheets are carried through everything but the tab of design data for the standards, and a prototype structure built, prior to populating the tabulation of standard designs.

10.9. Miscellaneous details related to the girders

Several sheets are needed to fully include the miscellaneous girder details not included in the girder details sheets. Specific details to include are:

- Closure pours.

- Diaphragms/closure formwork.
- Curb or concrete rail interface with girder edge.
- Keyways.
- Post-tensioning.
- Vertical deck elevation matching methods.
- Levelling pads.
- Any embedded items likely to be needed.
- Edge of end of girder shop alignment adjustment to deal with misalignment from changing skews each side of a pier

10.10. Prefabricated pier shafts detail sheets

- Includes tabular data for the load capacity and maximum effective length of each size pile or HSS planned.
- Only the largest of each HP series is compact for Grade 50 steel.
- Round HSS will need to have a diameter-to-wall thickness of about 63.8 maximum (this may be changed by proposed code revisions).
- Square HSS will need to have a size-to-wall thickness no greater than 35.7.
- Load per shaft at interior piers and abutments needs to be one of the pieces of design information provided for each tabular girder entry.

10.11. Precast pier caps

- Each size and load on a shaft has a standard cap size associated with it.
- The more severe skews may need cap flexural reinforcing that increases with the severity of the skew.
- Caps probably should be detailed in two-column or three-column units so that they can accommodate useful staging and have sizes that are easy to fabricate and handle. It is not known at this time whether the units should be left disconnected except for the upper closure diaphragm and deck keyways or should be connected as well.

10.12. Spread foundation support at abutments

- Deep foundation support should be able to use the same cap and shaft tabulations as the piers with the abutment reactions in the girder table.
- Foundation soil details will be needed for decked slab girders supported directly on GRS abutments. It is unnecessary and impractical to implement the retaining wall component of this system, since it would be too site specific. Standard retaining wall designs—either Block MSE or CIP walls—can be utilized for this element. Connection to the wall facing should be avoided to prevent detail dependencies between the two structures (wall and bridge).

10.13. Wingwalls

Two types of wingwall systems are expected to be developed:

- Precast concrete wingwalls made integral with the abutment and end of superstructure.
  - Severe skews may require special attention as the wingwalls resist lateral loads and the skew may contribute to additional wingwall loads.
  - Walls should not be turned back to run along and close to the edge of road. Minimum wall size occurs with a wall bisecting the acute angle between the edge of bridge approach and the line of the abutment.
- Small MSE walls
  - These walls take longer to construct than the precast concrete wingwalls and require different materials and skills to construct, but still may be a good choice in many locations.
  - Taller wall systems are efficient in MSE, but are recommended to be independent walls and not connected to the abutment.

10.14. Precast approach slabs

Consider using precast approach slabs with the same modular widths and key details as the slab girders, with spans from perhaps 10 feet to as much as 38 feet. A sleeper slab may be required at the end in some situations.

10.15. Backfill details

Current details can be used as a guide for developing these details.

10.16. Aesthetic enhancement details*

- Details (texture, color, relief, patterns, text, logos) on:
  a. Outside face of railing,
  b. Outside face of girder, and
  c. Face of wingwalls
- Color on shafts.

10.17. Slope protection details*

- Current slope paving details should be adequate.
- Riprap gabions are likely to be faster and less weather sensitive. Since they are flexible, less slope preparation should be needed than is needed for slope paving.
- There are other modular slope protection schemes.

10.18. Expansion joints at approach slabs*

Existing joint details may be acceptable. A retrofit detail may be helpful for those cases where the requirement for a joint is uncertain, or if approach pavement is later retrofitted with concrete pavement.

10.19. Bridge rails*

Existing rails should work, but a variation with a precast shell for the concrete part may speed construction considerably.

10.20. Fences attached to bridge rails*

Existing fence details should be acceptable.

10.21. Geometry sheets

Existing sheets should be fine, but since there is no capability of matching grade at mid-span, there is no reason to include nth points.

11. RECOMMENDATIONS

For maximum return on implementation costs, it is recommended that CDOT develop a new series of worksheets, rather than full standards. This will allow the details to be developed and used quickly ensuring benefits are achieved as soon as possible. New superstructure sections capable of use with accelerated bridge construction techniques should be developed as part of this effort. Three new precast prestressed concrete sections are recommended for development: decked slab girder, decked U-girder, and decked BT-girder. The worksheets should be developed in an incremental fashion beginning with easily achieved worksheets that will have immediate use and progressing to more complex elements with design utility at each stage.

The development and implementation order is recommended to be:

1. Worksheets for decked slab girders with moderate skew,
2. Worksheets for substructure compatible with ABC,
3. Worksheets for necessary table-driven design data for decked slab girders,
4. ABC bridge worksheets for decked U and decked BT-girders,
5. Worksheets for necessary table-driven design data for the decked U or decked BT-girders,
6. Worksheets for miscellaneous ABC details, such as:
    a. Precast concrete approach slabs,
    b. Precast concrete wingwalls,
    c. Expansion joints at approach slab with guidance to when needed,
    d. Slope protection,
    e. Altered bridge rails for ABC,
    f. Pier collision details—altered M-Standards sheets for 54-inch TL5 protection of piers,
    g. Integration worksheets to fit these together, i.e., worksheet for element description of the elements in a bridge and their relationship to each other, and
    h. Expand worksheet capability for more severe skews, etc.

To ensure that standards and worksheets are maintained, budget for sufficient resources to maintain standards and develop new worksheets. Assign a Champion and Assistant Champion for the long-term monitoring and progress of the project with enough time allocated for the task. Report on progress and prioritize needs each year.

It is best if the Champion can be filled on a long-term basis by someone with both technical and plan production expertise. Promotion of champions to largely administrative duties can hinder long-term viability. This effort is expected to take at least five years to complete, and requires maintenance for a long time to keep up with best practice, the AASHTO code, CDOT's Bridge Design Manual, and Colorado practice changes.

Focus can be maintained by utilizing real prototype bridges for each stage. Implement or improve a process for approval and release of worksheets (this applies to BDM as well) so completed work is not delayed indefinitely. Consider adding worksheets for partial-depth decked sections using similar to the decked superstructure sections recommended. This will require additional sheets describing the top mats of deck reinforcing.

Coordinate with other similar states to reach common ground on automated plan details and see if the AASHTO T-19 subcommittee on computers or AASHTO BridgeWare can provide assistance in developing automate plan sheet detailing.

Have champions keep up with potential code changes and their impact. Have champions and their assistants attend the AASHTO bridge subcommittee meetings to be aware of what other states are doing and what AASHTO is planning.

See if the CDOT personnel office can be convinced that higher pay levels should not be reserved only for those who manage, but also for technical leaders to maintain long-term stability for technical advisors and organizational memory on technical issues.

Consider a bulletin board or location for posting Q&A about technical design issues pertaining to CDOT Bridge, i.e., emailed questions forwarded to subject matter experts and responses posted. Break into sections about current worksheets, future worksheets, the BDM, etc. Questions have been asked and been answered before, but communication is mostly one-on-one and not shared laterally. Also, questions and answers are not shared forward in time. Most issues have come up before.

Design and build a prototype bridge. The minimum for this is to detail the framework of the worksheets for the girders in one of the suggested types, and the framework for the precast substructure. Make a custom design using these worksheet frameworks as a part of the design plans. The frameworks for the worksheets can be completed using data for other designs and updated using what is learned from this process.

Potentially useful related research:

- Strength of overlapping loop connections, including higher strength steels, such as 75 and 100 ksi yield reinforcing and larger bars. This can remove excess conservatism.
- Low shrinkage, low cracking, fast setting 6 ksi concrete for keyways, continuity closures, shaft fill, and rails and curbs. Needed for fast construction and long-term durability.
- Stay-in-place fiber reinforced cementitious composites (FRCC) formwork to eliminate the need for formwork removal.
- Monitor effectiveness and variability of actual camber control. This can potentially reduce or eliminate, in some cases, the amount of monostrand prestressing needed, reducing cost and simplifying construction.
- Monitor actual live-load “in service” deflections, a critical design criterion that may have a low correlation to actual behaviour or actual requirements. This could allow shallower structures.

- Determine actual temperature movements, both absolute and relative to approaches. Better data may allow longer integral structures, decreasing costs, decreasing maintenance, and increasing life for longer integral structures.
- Continue the investigation into the effect of traffic and local environment on the chloride levels at the surface of various parts of bridges.
- Investigate the use of mobile volumetric mixer trucks or trailers. These may be appropriate for the small concrete volumes and production rates needed for the joints between precast units, and for fast setting concrete mixes. They may also have a place at CDOT for rapid renewal and repair work.
- Encourage AASHTOWARE to change BrR and BrD to separate the continuity connection stage from the composite slab-setting phase of construction in order to accommodate shored construction of pre-decking on units to be connected later.

Challenges: This is a rather broad topic. The authors see these challenges as largely organizational and matching the challenges for CDOT Staff Bridge in general: training, code changes, maintenance of the standards, budget, and manpower in the face of competing needs. Standard bridges may help a bit by reducing the breadth and depth of knowledge needed for a typical journeyman designer or detailer, but the champion and assistant champion will still need this technical breadth and depth. It will need to be at the current edge of the state-of-the-art in order to make effective decisions for the future of standards that may shape the technology and problems of bridges that form a significant portion of the state's structure inventory over the next century. One of these technical issues is the future of bridge deck design, not an issue specific to the standard bridges, but critically important none the less. The authors envision four methods, all intended to create bridge decks that will last for 75 to 100 years without replacement:

- Black bar reinforcing for locations with no chance of bar corrosion (this location may not exist often enough for Colorado to worry about).
- Decks protected by membrane, asphalt, and epoxy coated or corrosion resistant (MMFXII) reinforcing for bridges carrying roads paved in asphalt.
- Decks protected by sealers and corrosion resistant bars.
- Decks protected by the use of stainless steel reinforcing.

12. GLOSSARY

Abutment: The end support of a bridge. Usually incorporates a backwall to separate the girders from the soil in the approaching road.

Accelerated Bridge Construction (ABC): The name for an ongoing effort to speed construction, thereby reducing user costs. This is an ongoing focus of the Federal Highway Administration (FHWA).

American Association of State Highway and Transportation Officials (AASHTO): The governing and code creation body for Highway design in the United States (US)

Load and Resistance Factor Design (LRFD) Bridge Design Specifications: The most modern bridge design practice, LRFD, codified. This attempts to be a reliability based method. Gradually more and more design aspects have their design method calibrated against desired levels of reliability.

Approach slab: Transitions the surface of the bridge to the surface of the approaching road. This is sometimes needed and sometimes not needed.

AutoCAD: A CAD program.

Automated design: Sometimes called Computer aided Design and Drafting (CADD).

Back wall: Separates approach road soil from girders.

Backfill: Soil used to fill a hole, including holes made to build foundation elements of a bridge.

Bearing: For bridges, a structural element to allow relative movement in one or several directions of a supported structure relative to its support.

Box culvert: Basically a large rectangular pipe.

Bridge Automated Design and Detailing (BRADD): A CADD program for designing and detailing single span bridges.

BT girder: Bulbed Tee Girder (BT), an I-girder shape with a very wide top flange

Camber: The humping up of a horizontal structure. Sometimes built in deliberately to follow a road profile, but for prestressed concrete structures more often a consequence of longitudinal forces applied along the bottom of a structure. For example, pretensioning or post-tensioning applied to strengthen members.

Cap: A Structural element to connect columns and girders, especially when girders do not connect directly to columns.

Cast-in-place (CIP): Concrete formed, poured and cured in its final location.

Columbus Engineering Co. (CEC) Engineering: An Engineering firm based in Columbus, Ohio.

Colorado Department of Transportation (CDOT): A division of the executive department of the government of the State of Colorado USA

Bridge Design Manual (BDM): A collection of policies specific to CDOT structures, but used by others as well

Colorado Miscellaneous Standard Plans (M-Standards): Some pre-approved standard plans for use by CDOT for their highway structures, but used by others as well

Computer Aided Drafting (CAD): Graphics programs intended as a means of drawing plans.

Concrete box culvert: A box culvert made from concrete.

CONSPLICE: An analysis program for concrete composite, precast, prestressed, post-tensioned, or reinforced concrete girders that allows for various combinations and the splicing of the various sections.

Construction cost: The cost to construct a project or element of a project, usually including overhead, but not planning costs.

Continuous: Structural members do not stop and start at each support.

Cost-benefit ratio: Simply the ratio of costs to an estimated value of the benefits provided by the product of those costs.

Cracking: Crack formation after construction or initial placement of materials. Common or even necessary in construction with concrete, but the size and amount of cracking contributes to deterioration, and very and long cracks can cause a significant loss of strength.

CT load: The load from collision of a heavy truck directly into a bridge element (not a glancing impact)

Dead load: The weight of a structure.

Deck: The structural element that supports the traffic.

Deck slab: See deck

Design variable: Designing requires computations that require input data for those computations. This input data are design variables.

Diaphragm: A form of bracing member.

Exterior girder: The girder at the outside edge of the bridge. Since the other girders are on only one side it is less able to share loads with adjacent girders. This can result in a larger portion of live loads to this girder if they are positioned over the girder. This also results in a higher risk of failure if overloaded.

Ultra High Performance Concrete (UHPC): Concrete with high tensile and compressive strength, high crack resistance, ductility, and with self-consolidating concrete (SCC) characteristics

Fiber Reinforced Cementitious Composite (FRCC): A cement based material with reinforcing for tension fiber (usually over 1% by volume). This usually has some ductility and substantial resistance to cracking. A common example available from lumber yards is tile backer board. This is coming into use as a potentially thin construction material that can now be used outside of the factories than make such things as tile backer board. UHPC is usually an FRCC, but is normally more fluid (SCC) and has an unusually high strength as well, characteristics which are not necessarily needed in all applications. For this report, this material is considered for stay-in-place formwork since it can be worked and connected similarly to plywood used for concrete forms, has a similar strength as plywood, but does not deteriorate with time like plywood, and therefore, does not need to be removed once the concrete is set. Unlike plywood, it can be cast into various shapes.

FIR: A meeting that occurs once costs are relatively settled and design issues identified. This meeting usually makes sure everyone agrees on scope and is designing to the same criteria. For Bridges this means that the data that would be on a general layout is agreed to.

FOR: A meeting similar to the FIR, but all the, design, plan sheets, and quantities are included.

Foundation: Normally the element that transmits the loads to the earth.

Geometry: The detailed shape of a road or structure.

Geometry control: Usually reference data that other aspects of geometry are measured against, but also means to assure that the final shape of a bridge conforms well enough to the desired shape.

Geosynthetic Reinforced Soil-Integrated Bridge System (GRS-IBS): A combination of Retaining wall of the reinforced soil type (MSE) with the superstructure end sitting directly on the soil without a cap or structural elements carrying the structure and live-load forces to a lower level.

Girder: A horizontal beam or member that carries load from where it is applied to a support by means of internal force couples. As opposed to a truss or arch which do not have significant internal couples in their members to carry these loads

Haunching: In this context, the girder gets deeper near the piers. Also, a term for a concrete build up between girders and decks to adjust the geometry of the deck to differ from that of the girder.

I girder: A girder with a cross section that is roughly I shaped.

Implementation cost: For this report, the costs associated with implementing the recommendation. Mostly labor costs with associated overhead.

Integral construction: A structure that is made in a single piece. Since failure and deterioration usually originate from at the junctures of separate pieces, these structures have lower rates of deterioration, require less maintenance, and are tougher due to having many ways to transmit a load from where it is applied to the ground. These many ways can make design more difficult as it can be uncertain how loads are transmitted. Often it is unimportant whether the design is precise or not if all the elements have some ductility (ability to bend without breaking).

Interior girder: A girder that has at least one other girder on each side. These tend to share loads applied to them with girders on both sides and be more resistant to failure than exterior girders as a result.

Joint: A small gap between structural elements, usually to simplify analysis or to allow motions from temperature changes, though sometimes simply a result of the pieces the structure is built from.

Jointless: Usually refers to no joints in the deck of a bridge from the back of the abutment at one end to the back of the abutment at the other. Integral bridges are intrinsically jointless, but often jointless bridges contain bearings, and are therefore are not Integral.

LDFAC: Live-load Distribution Factors (LDFAC), a program to calculate how live loads should be distributed to girders, and from girders to caps or substructure.

Life cycle cost: The total cost to build and maintain a structure from conception to ultimate replacement or demise.

Literature review: A search for other reports on the same topic or closely related topics. A literature review is necessary to address the purpose of making a report or a decision about what additional problems need to be addressed. This is important to making decisions on a new topic.

Live load: For highway bridges, the loads due to the moving things the bridge is designed to carry, mostly the weight of trucks, cars, and pedestrians.

Live-load distribution: How much of the live load flows to a particular resistance path such as a particular girder or bearing.

Live-load deflection: Deflections from live load. Usually midspan girder deflections from the live load specified for this. Normally restricted to a low value to control other related factors such as vibration. Limits on this usually helps assure sufficient stiffness to avoid problems from factors not addressed by the design codes, such as variability of dead-load deflections, flutter in wind, unacceptable creep deflections, etc.

Mechanically stabilized earth (MSE): Soil or earth with tension reinforcement to improve behaviour. This can allow higher loads to be applied by foundations, and can allow steeper slopes than could naturally occur.

Merit: A measure of the weight of material used in a bridge, expressed in terms of what those materials cost in 1994. This includes substructure costs since this is a large factor in choosing the optimum spans. If this was reformatted for this year's costs, the numbers would be perhaps 2.5 to 3 times larger. A useful measure of what precast girder type and span length is most cost effective. Best used as a decision aid in choosing girder type and span lengths. It can reveal relative cost differences between options, but is not particularly useful for estimating total costs.

MicroStation: A CAD program. Currently used by all states. Fills the role formerly filled by AutoCAD in Colorado.

Moment: Is a measure the tendency of a force to cause a body to rotate about a specific point or axis. It is what makes beams bend.

NExt beam: New England eXtreme Tee (NEXT). A new girder type being used around the country. It fills the gap that twin tees did not fill well due to their narrow stem that did not allow for continuity or substantial prestress force.

Off-system: A categorization of bridges that means they are not owned by the State of Colorado, but by a division of local government. About half the highway bridges in Colorado are not owned by the state.

On-system: A categorization of bridges that means they are owned by the State of Colorado. About half the highway bridges in Colorado are owned by the state. The number of bridges changes a bit from year to year.

Pier: A bridge support that supports the girders above the ground away from the approach.

Pile: A vertical member embedded in the ground at the bottom to transmit the bridge loads to the ground.

Plan sheets: The individual drawing sheets that taken together make the project plans, usually a larger sheet than used for specifications.

Post-tensioning: Applying a compressive force to concrete after it is cast and set up. Usually involves a tension element inside the concrete.

Precast: Concrete that is poured and cured somewhere other than its final location.

Predecked: A member with the deck precast on top of it.

Prestressed: Concrete with compression added to it to reduce or eliminate cracking from tension. Concrete is relatively weak in tension.

Pretensioning: A way of making prestressed concrete by stretching cables, pouring concrete around them, and then cutting the cables where they come out of the concrete. The cables then transfer there force to the concrete from their original anchorage, putting the concrete into compression. Inexpensive but generally impractical outside of a fabrication plant.

PSGLRFD: A design and capacity rating program for precast prestressed girders.

Rail: For the purposes of this report, the rail is a horizontal feature to prevent trucks, cars, and pedestrians from falling off the structure.

Rolled beam: Standardized steel beams made in a mill by rolling hot from ingots cast from molten steel. These usually are in an “I” shape when used a bridge girders.

Rubblization: The accumulation of cracks to the extent the resulting concrete approaches the consistency of gravel.

Service limit states: Design limits that do not reflect the strength of an element, but its functionality or durability. The limits are much fuzzier to define since functionality and durability are much harder to either define or test than strength, are highly variable, and as such are mostly historically based

Shaft: The vertical load carrying elements of piers or abutments. In this case, this usually means the same as pile. The term was used because as proposed the piles are not the materials or methods usually used in Colorado, sharing more in common with columns and drilled shafts (sometimes called caissons in Colorado), and for one foundation option these are definitely not piles as they would be embedded on a footer rather than the ground.

Skew: The common structure definition is the angle between a perpendicular to the girders and the line of support or cap of a pier or abutment.

Slope protection: Surface material placed on the slopes under a bridge to reduce erosion. Due to shade and grade, this area often does not stabilize with vegetation. In addition, it is often subject to slightly concentrated drainage flow from the approach roadway that can erode sloped soil.

Span: The spacing between supports. For structural purposes of designing the girders this is usually measured along the girders.

Spread foundation: A slab or block at the bottom of a column or wall to spread the load sufficiently that the load will be reliability supported.

Standard bridge plans: A standard bridge plan is one that contains all critical design information for the bridge or element, and requires no further design or modification for use. Often preapproved so that an engineer's stamp is not required.

Strength limit states: Design conditions for which the structure only needs sufficient strength to carry the load specified. Strength is usually taken as a load capability that can be reliably achieved for which the member retains some functionality.

Substructure: The collection of structure elements that carry loads from the ground to the girders to the primary longitudinal load carrying members.

Superelevation: Transverse slope of the deck, for drainage, or to maintain an acceptable ride and vehicle handling when considering centripetal force of a vehicle moving along a horizontally curved road.

Superstructure: The collection of structural elements above the substructure. Usually girders, diaphragms, and deck.

Tensile stress: A force per unit area that tends to pull a material apart.

Thermogradient: A difference of temperature through the thickness of a structure. As different parts expand or contract differently due to temperature, stresses and bending occur.

Truss: A major load-carrying member composed of smaller elements usually forming triangles, and usually considered as only carrying axial force. This is often a simplification useful for design and analysis purposes, as many of these are actually frames or space frames that are much more complicated in behavior.

U girder: A girder for which a section looks like the letter U. Often called tub girders or tubs. These tend to be more stable than I shaped girders, and when they have a slab on top, have great strength and stiffness for resisting twisting.

Vertical curve: Curvature of a road in the up and down directions. Use to improve ride, and prevent the bottoms of vehicles between axles from scraping the road.

Wingwall: A small wall that holds back soil at the corners of a bridge is necessary because the level of the soil just in front of an abutment is usually several feet below the road on the approach side of the abutment, and the two levels do not come together for at least several feet.

Worksheet: A drawing much like a standard plan sheet. It may require additional information or details by the designer. Some worksheets have all details and most design information, and others very little, forming only a framework for custom details. Worksheets do not constitute preapproved plans and it is important for the engineer to verify their appropriate use, completeness, and the accuracy of the data on them.

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Appendix A. Tabulation of Girder Analysis

Notes:

ID names for tables and files on the attached CD: "Depth in inches" + "Girder type" of DS (decked slab girder), DU (Decked U girder), DNX (decked Next beam), or DBT (Decked BT girder)+ "C" for thicker web + "Top of deck width of girder in whole feet". A "-" after the file name or in place of the X or T indicates a run to define a shorter span's behaviour at the point where a lower cost wider section becomes feasible. Similarly a "~" indicates the file name of a run made to minimize interpolation errors in the data provided.

Width defines the spacing center to center of longitudinal joints between decked precast girders

Slab defines the thickness of the closure in the longitudinal joints between decked precast girders

Deck concrete f'c = 6,000 psi

Added (non-composite) DL = 0 psf

End cross section same as interior

Strand used is 270 ksi 0.6-inch low-lax

Simple spans are pinned connections at both ends

End spans are partly fixed at one end

Interior spans are partly fixed at both ends

Humidity is assumed as 60 percent

Abutment spread support width is assumed based on 5 TSF peak factored load bearing pressure, 3.3 TSF average with load centered 1/3 of that width from girder or footing end.

Note the charts are broken into three sections, each showing a different group of design variables and calculation results. Each part is about 8 pages long.

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
10DS15I-	18.1	16.00	9	1012	1800.0	5.0	15000	10.0	180.00	180	9.0	4000	6000	16	0.66
10DS15I	24.0	16.00	9	1012	1800.0	5.0	15000	10.0	180.00	180	9.0	4000	6000	26	0.66
13DS15I-	24.1	16.00	12	1012	2367.0	6.5	33245	13.0	180.00	180	12.0	4000	6000	18	0.70
13DS15I	33.0	16.00	12	1012	2367.0	6.5	33245	13.0	180.00	180	12.0	4000	6000	34	0.70
17DS15I-	33.1	16.00	16	1012	3087.0	8.5	74092	17.0	180.00	180	16.0	4000	6000	24	0.73
17DS15I	45.0	16.00	16	1012	3087.0	8.5	74092	17.0	180.00	180	16.0	4000	6000	48	0.73
20DS15I-	45.1	16.00	19	1012	3600.1	10.0	120000.1	20.0	180.00	180	19.0	4000	6000	42	0.70
20DS15I	56.0	16.00	19	1012	3600.1	10.0	120000.1	20.0	180.00	180	19.0	4000	6000	70	0.70
32DU15I-	34.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	12	0.75
32DU15I~	50.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	24	0.75
32DU15I	65.0	16.00	8	1012	2266.6	21.8	219173.8	32.0	10.30	180	9.0	4000	6000	34	0.68
32DU10I-	65.1	10.67	8	675	1708.6	19.9	191357.1	32.0	10.30	118	9.0	4000	6000	24	0.75
32DU10I	90.0	10.67	8	675	1708.6	19.9	191357.1	32.0	10.30	118	9.0	4000	6000	44	0.75
32DU7I-	91.1	8.00	8	506	1429.6	18.4	170213.8	32.0	10.30	87	9.0	4000	6000	38	0.75
32DU7I	100.0	8.00	8	506	1429.6	18.4	170213.8	32.0	10.30	87	9.0	4193	6000	46	0.75
32DU-15I	48.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	22	0.75
32DUC15I	79.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4157	6000	56	0.75
32DU-10I	79.1	10.67	8	675	1783.3	19.8	193860.1	32.0	15.45	118	9.0	4000	6000	36	0.75
32DUC10I	91.0	10.67	8	675	1783.3	19.8	193860.1	32.0	15.45	118	9.0	4000	6000	46	0.75
33DN-15I	34.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4000	6000	14	0.70
33DN~15I	52.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4000	6000	26	0.70
33DNX15I	70.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4180	6000	48	0.70
33DN-10I	70.1	10.67	8	675	1739.3	22.2	149225.1	33.0	26.00	118	9.0	4000	6000	36	0.71
33DNX10I	80.0	10.67	8	675	1739.3	22.2	149225.1	33.0	26.00	118	9.0	4608	6000	48	0.71
33DNX7I-	80.1	8.00	8	506	1460.3	21.0	134165.5	33.0	26.00	87	9.0	4074	6000	36	0.73
33DNX7I	88.0	8.00	8	506	1460.3	21.0	134165.5	33.0	26.00	87	9.0	5071	6000	44	0.73
38DU15I-	34.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	10	0.71
38DU15I~	65.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	28	0.71
38DU15I	96.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	56	0.71
38DU10I-	96.1	10.67	8	675	1661.4	24.2	294461	38.0	10.30	118	9.0	4000	6000	40	0.75
38DU10I	111.0	10.67	8	675	1661.4	24.2	294461	38.0	10.30	118	9.0	4000	6000	52	0.75

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
38DU7I-	111.1	8.00	8	506	1382.4	22.4	263865.4	38.0	10.30	87	9.0	4000	6000	44	0.75
38DU7I	123.0	8.00	8	506	1382.4	22.4	263865.4	38.0	10.30	87	9.0	4310	6000	54	0.75
38DU-15I	56.0	16.00	8	1012	2450.4	25.7	336250.6	38.0	15.46	180	9.0	4000	6000	22	0.73
38DUC15I	92.0	16.00	8	1012	2450.4	25.7	336250.6	38.0	15.46	180	9.0	4000	6000	54	0.73
38DU-10I	92.1	10.67	8	664	1892.4	23.4	288525.2	38.0	15.46	118	9.0	4000	6000	40	0.73
38DUC10I	113.0	10.67	8	664	1892.4	23.4	288525.2	38.0	15.46	118	9.0	4000	6000	62	0.73
38DUC7I-	113.1	8.00	8	506	1490.1	22.1	269229.9	38.0	15.46	87	9.0	4000	6000	46	0.75
38DUC7I	125.0	8.00	8	506	1490.1	22.1	269229.9	38.0	15.46	87	9.0	4115	6000	58	0.75
41DN-15I	60.0	16.00	8	1012	2492.0	29.6	306188.4	41.0	25.00	180	9.0	4000	6000	26	0.75
41DNX15I	94.0	16.00	8	1012	2492.0	29.6	306188.4	41.0	25.00	180	9.0	4960	6000	58	0.75
41DN-10I	94.1	10.67	8	675	1934.0	27.6	268119.6	41.0	25.00	118	9.0	4000	6000	42	0.75
41DNX10I	108.0	10.67	8	675	1934.0	27.6	268119.6	41.0	25.00	118	9.0	4712	6000	58	0.75
41DNX7I-	108.1	8.00	8	506	1655.0	26.1	240413	41.0	25.00	87	9.0	4000	6000	48	0.75
41DNX7I	120.0	8.00	8	506	1655.0	26.1	240413	41.0	25.00	87	9.0	4805	6000	60	0.75
44DU15I-	64.0	16.00	8	1012	2406.6	30.3	513364.1	44.0	10.30	180	9.0	4000	6000	24	0.70
44DU15I	94.0	16.00	8	1012	2406.6	30.3	513364.1	44.0	10.30	180	9.0	4000	6000	44	0.70
44DU10I-	94.1	10.67	8	664	1848.6	27.5	448112.5	44.0	10.30	118	9.0	4000	6000	32	0.74
44DU10I	122.0	10.67	8	664	1848.6	27.5	448112.5	44.0	10.30	118	9.0	4000	6000	54	0.74
44DU7I-	122.1	8.00	8	506	1569.6	25.4	399046.8	44.0	10.30	87	9.0	4000	6000	50	0.75
44DU7I	144.0	8.00	8	506	1569.6	25.4	399046.8	44.0	10.30	87	9.0	4760	6000	70	0.75
48DB-10I	34.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	4000	6000	6	0.75
48DB~10I	76.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	4000	6000	22	0.75
48DBT10I	117.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	5984	6000	48	0.75
48DBT7I-	117.1	8.00	8	506	1300.5	33.0	345263.8	47.5	7.00	87	9.7	4387	6000	40	0.70
48DBT7I	135.0	8.00	8	506	1300.5	33.0	345263.8	47.5	7.00	87	9.7	5799	6000	54	0.70
48DBT5I-	135.1	5.33	8	342	1008.0	29.2	276309	47.5	7.00	56	9.7	4000	6000	38	0.73
48DBT5I	154.0	5.33	8	342	1008.0	29.2	276309	47.5	7.00	56	9.7	5302	6000	52	0.73
51DU15I-	72.0	16.00	8	1012	2452.4	35.2	718062.3	50.6	10.30	180	9.0	4000	6000	24	0.75
51DU15I	92.0	16.00	8	1012	2452.4	35.2	718062.3	50.6	10.30	180	9.0	4000	6000	36	0.75
51DU10I-	92.1	10.67	8	664	1894.4	32.0	628472.4	50.6	10.30	118	9.0	4000	6000	28	0.75

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
51DU10I	119.0	10.67	8	664	1894.4	32.0	628472.4	50.6	10.30	118	9.0	4000	6000	42	0.75
51DU7I-	119.1	8.00	8	506	1615.4	29.6	561541.1	50.6	10.30	87	9.0	4000	6000	38	0.75
51DU7I	140.0	8.00	8	506	1615.4	29.6	561541.1	50.6	10.30	87	9.0	4491	6000	52	0.75
60DB-10I	76.0	10.67	8	664	1645.0	42.7	625928	59.5	7.00	118	9.7	4000	6000	18	0.73
60DBT10I	137.0	10.67	8	664	1645.0	42.7	625928	59.5	7.00	118	9.7	5171	6044	54	0.73
60DBT7I-	137.1	8.00	8	506	1370.5	40.2	572603.7	59.5	7.00	87	9.7	4321	6000	38	0.75
60DBT7I	165.0	8.00	8	506	1370.5	40.2	572603.7	59.5	7.00	87	9.7	5776	6649	58	0.75
60DBT5I-	165.1	5.33	8	342	1091.5	36.4	494111.9	59.5	7.00	56	9.7	4168	6000	42	0.74
60DBT5I	181.0	5.33	8	342	1091.5	36.4	494111.9	59.5	7.00	56	9.7	5131	6000	52	0.74
63DU15I-	80.0	16.00	8	1012	2576.9	43.5	1224488	62.6	10.30	180	9.0	4000	6000	24	0.75
63DU15I	87.0	16.00	8	1012	2576.9	43.5	1224488	62.6	10.30	180	9.0	4000	6000	28	0.75
63DU10I-	87.1	10.67	8	664	2018.9	39.5	1068904	62.6	10.30	118	9.0	4000	6000	20	0.75
63DU10I	112.0	10.67	8	664	2018.9	39.5	1068904	62.6	10.30	118	9.0	4000	6000	32	0.75
63DU7I-	112.1	8.00	8	506	1739.9	36.5	955020.1	62.6	10.30	87	9.0	4000	6000	30	0.75
63DU7I	130.0	8.00	8	506	1739.9	36.5	955020.1	62.6	10.30	87	9.0	4000	6000	40	0.75
69DB-10I	84.0	10.67	8	664	1713.0	49.0	898719	68.5	7.00	118	9.7	4000	6000	18	0.72
69DBT10I	132.0	10.67	8	664	1713.0	49.0	898719	68.5	7.00	118	9.7	4629	6000	38	0.72
69DBT7I-	132.1	8.00	8	506	1433.5	46.1	820427.3	68.5	7.00	87	9.7	4000	6000	32	0.75
69DBT7I	158.0	8.00	8	506	1433.5	46.1	820427.3	68.5	7.00	87	9.7	5239	6000	44	0.75
69DBT5I-	158.1	5.33	8	342	1155.0	41.7	707991	68.5	7.00	56	9.7	4000	6000	32	0.75
69DBT5I	196.0	5.33	8	342	1155.0	41.7	707991	68.5	7.00	56	9.7	5649	6362	52	0.75
75DU15I-	64.0	16.00	8	1012	2700.8	51.5	1896714	74.6	10.30	180	9.0	4000	6000	14	0.65
75DU15I	83.0	16.00	8	1012	2700.8	51.5	1896714	74.6	10.30	180	9.0	4000	6000	22	0.65
75DU10I-	83.1	10.67	8	664	2142.8	46.7	1649631	74.6	10.30	118	9.0	4000	6000	16	0.75
75DU10I	105.0	10.67	8	664	2142.8	46.7	1649631	74.6	10.30	118	9.0	4000	6000	24	0.75
75DU7I-	105.1	8.00	8	506	1863.8	43.2	1472110	74.6	10.30	87	9.0	4000	6000	24	0.75
75DU7I	121.0	8.00	8	506	1863.8	43.2	1472110	74.6	10.30	87	9.0	4000	6000	32	0.75
10DS15E-	16.1	16.00	9	1012	1800.0	5.0	15000	10.0	180.00	180	9.0	4000	6000	16	0.66
10DS15E	22.0	16.00	9	1012	1800.0	5.0	15000	10.0	180.00	180	9.0	4000	6000	28	0.66
13DS15E-	22.1	16.00	12	1012	2367.0	6.5	33245	13.0	180.00	180	12.0	4000	6000	20	0.68

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
13DS15E	31.0	16.00	12	1012	2367.0	6.5	33245	13.0	180.00	180	12.0	4000	6000	36	0.68
17DS15E-	31.1	16.00	16	1012	3087.1	8.5	74092.1	17.0	180.00	180	16.0	4000	6000	28	0.70
17DS15E	42.0	16.00	16	1012	3087.1	8.5	74092.1	17.0	180.00	180	16.0	4000	6000	58	0.70
20DS15E-	42.1	16.00	19	1012	3600.1	10.0	120000.1	20.0	180.00	180	19.0	4000	6000	42	0.70
20DS15E	51.0	16.00	19	1012	3600.1	10.0	120000.1	20.0	180.00	180	19.0	4000	6000	66	0.70
32DU15E-	31.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	12	0.73
32DU15E~	44.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	22	0.73
32DU15E	56.0	16.00	8	1012	2266.6	21.8	219173.8	32.0	10.30	180	9.0	4000	6000	32	0.70
32DU10E-	56.1	10.67	8	675	1708.6	19.9	191357.1	32.0	10.30	118	9.0	4000	6000	22	0.72
32DU10E	82.0	10.67	8	675	1708.6	19.9	191357.1	32.0	10.30	118	9.0	4000	6000	46	0.72
32DU7E-	82.1	8.00	8	506	1429.6	18.4	170213.8	32.0	10.30	87	9.0	4000	6000	36	0.73
32DU7E	91.0	8.00	8	506	1429.6	18.4	170213.8	32.0	10.30	87	9.0	4000	6000	44	0.73
32DU-15E	56.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	34	0.73
32DUC15E	72.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	54	0.73
32DU-10E	72.1	10.67	8	675	1783.3	19.8	193860.1	32.0	15.45	118	9.0	4000	6000	38	0.71
32DUC10E	83.0	10.67	8	675	1783.3	19.8	193860.1	32.0	15.45	118	9.0	4000	6000	52	0.71
33DN-15E	31.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4000	6000	14	0.75
33DN~15E	47.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4000	6000	26	0.75
33DNX15E	63.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4488	6000	44	0.75
33DN-10E	63.1	10.67	8	675	1739.3	22.2	149225.1	33.0	26.00	118	9.0	4000	6000	34	0.71
33DNX10E	73.0	10.67	8	675	1739.3	22.2	149225.1	33.0	26.00	118	9.0	4435	6000	46	0.71
33DNX7E-	73.1	8.00	8	506	1460.3	21.0	134165.5	33.0	26.00	87	9.0	4000	6000	32	0.75
33DNX7E	80.0	8.00	8	506	1460.3	21.0	134165.5	33.0	26.00	87	9.0	4766	6000	40	0.75
38DU15E-	31.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	10	0.66
38DU15E~	54.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	24	0.66
38DU15E	77.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	46	0.66
38DU10E-	77.1	10.67	8	675	1661.4	24.2	294461	38.0	10.30	118	9.0	4000	6000	32	0.71
38DU10E	101.0	10.67	8	675	1661.4	24.2	294461	38.0	10.30	118	9.0	4135	6000	54	0.71
38DU7E-	101.1	8.00	8	506	1382.4	22.4	263865.4	38.0	10.30	87	9.0	4000	6000	44	0.72
38DU7E	111.0	8.00	8	506	1382.4	22.4	263865.4	38.0	10.30	87	9.0	4120	6000	52	0.72

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
38DU-15E	64.0	16.00	8	1012	2450.4	25.7	336250.6	38.0	15.46	180	9.0	4000	6000	32	0.73
38DUC15E	89.0	16.00	8	1012	2450.4	25.7	336250.6	38.0	15.46	180	9.0	4278	6000	60	0.73
38DU-10E	89.1	10.67	8	664	1892.4	23.4	288525.2	38.0	15.46	118	9.0	4000	6000	42	0.75
38DUC10E	102.0	10.67	8	664	1892.4	23.4	288525.2	38.0	15.46	118	9.0	4000	6000	56	0.75
38DUC7E-	102.1	8.00	8	506	1490.1	22.1	269229.9	38.0	15.46	87	9.0	4000	6000	44	0.75
38DUC7E	114.0	8.00	8	506	1490.1	22.1	269229.9	38.0	15.46	87	9.0	4148	6000	54	0.75
41DN-15E	68.0	16.00	8	1012	2492.0	29.6	306188.4	41.0	25.00	180	9.0	4000	6000	36	0.75
41DNX15E	85.0	16.00	8	1012	2492.0	29.6	306188.4	41.0	25.00	180	9.0	5353	6000	56	0.75
41DN-10E	85.1	10.67	8	675	1934.0	27.6	268119.6	41.0	25.00	118	9.0	4000	6000	40	0.75
41DNX10E	98.0	10.67	8	675	1934.0	27.6	268119.6	41.0	25.00	118	9.0	4960	6000	54	0.75
41DNX7E-	98.1	8.00	8	506	1655.0	26.1	240413	41.0	25.00	87	9.0	4000	6000	44	0.75
41DNX7E	109.0	8.00	8	506	1655.0	26.1	240413	41.0	25.00	87	9.0	4943	6000	56	0.75
44DU15E-	68.0	16.00	8	1012	2406.6	30.3	513364.1	44.0	10.30	180	9.0	4000	6000	30	0.73
44DU15E	94.0	16.00	8	1012	2406.6	30.3	513364.1	44.0	10.30	180	9.0	4134	6000	52	0.73
44DU10E-	94.1	10.67	8	664	1848.6	27.5	448112.5	44.0	10.30	118	9.0	4000	6000	38	0.74
44DU10E	122.0	10.67	8	664	1848.6	27.5	448112.5	44.0	10.30	118	9.0	4000	6000	62	0.74
44DU7E-	122.1	8.00	8	506	1569.6	25.4	399046.8	44.0	10.30	87	9.0	4000	6000	52	0.75
44DU7E	139.0	8.00	8	506	1569.6	25.4	399046.8	44.0	10.30	87	9.0	4644	6000	68	0.75
48DB-10E	31.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	4000	6000	6	0.75
48DB~10E	67.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	4000	6000	20	0.75
48DBT10E	103.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	5887	6000	42	0.75
48DBT7E-	103.1	8.00	8	506	1300.5	33.0	345263.8	47.5	7.00	87	9.7	4375	6000	34	0.73
48DBT7E	119.0	8.00	8	506	1300.5	33.0	345263.8	47.5	7.00	87	9.7	5771	6000	46	0.73
48DBT5E-	119.1	5.33	8	342	1021.5	30.3	307842.6	47.5	7.00	56	9.7	4000	6000	32	0.73
48DBT5E	146.0	5.33	8	342	1021.5	30.3	307842.6	47.5	7.00	56	9.7	5921	6184	52	0.73
51DU15E-	84.0	16.00	8	1012	2452.4	35.2	718062.3	50.6	10.30	180	9.0	4000	6000	36	0.75
51DU15E	92.0	16.00	8	1012	2452.4	35.2	718062.3	50.6	10.30	180	9.0	4000	6000	42	0.75
51DU10E-	92.1	10.67	8	664	1894.4	32.0	628472.4	50.6	10.30	118	9.0	4000	6000	32	0.75
51DU10E	119.0	10.67	8	664	1894.4	32.0	628472.4	50.6	10.30	118	9.0	4520	6000	50	0.75
51DU7E-	119.1	8.00	8	506	1615.4	29.6	561541.1	50.6	10.30	87	9.0	4000	6000	42	0.75

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
51DU7E	140.0	8.00	8	506	1615.4	29.6	561541.1	50.6	10.30	87	9.0	4576	6000	56	0.75
60DB-10E	64.0	10.67	8	664	1645.0	42.7	625928	59.5	7.00	118	9.7	4000	6000	16	0.75
60DBT10E	130.0	10.67	8	664	1645.0	42.7	625928	59.5	7.00	118	9.7	5887	6752	54	0.75
60DBT7E-	130.1	8.00	8	506	1370.5	40.2	572603.7	59.5	7.00	87	9.7	4646	6000	42	0.73
60DBT7E	146.0	8.00	8	506	1370.5	40.2	572603.7	59.5	7.00	87	9.7	5795	7312	52	0.75
60DBT5E-	146.1	5.33	8	342	1091.5	36.4	494112	59.5	7.00	56	9.7	4000	6000	36	0.75
60DBT5E	168.0	5.33	8	342	1091.5	36.4	494112	59.5	7.00	56	9.7	5285	6715	50	0.75
63DU15E-	68.0	16.00	8	1012	2576.9	43.5	1224488	62.6	10.30	180	9.0	4000	6000	20	0.75
63DU15E	87.0	16.00	8	1012	2576.9	43.5	1224488	62.6	10.30	180	9.0	4000	6000	32	0.75
63DU10E-	87.1	10.67	8	664	2018.9	39.5	1068904	62.6	10.30	118	9.0	4000	6000	24	0.75
63DU10E	112.0	10.67	8	664	2018.9	39.5	1068904	62.6	10.30	118	9.0	4000	6000	36	0.75
63DU7E-	112.1	8.00	8	506	1739.9	36.5	955020.1	62.6	10.30	87	9.0	4000	6000	32	0.75
63DU7E	130.0	8.00	8	506	1739.9	36.5	955020.1	62.6	10.30	87	9.0	4000	6000	44	0.75
69DB-10E	72.0	10.67	8	664	1713.0	49.0	898719	68.5	7.00	118	9.7	4000	6000	16	0.73
69DBT10E	132.0	10.67	8	664	1713.0	49.0	898719	68.5	7.00	118	9.7	4544	6000	44	0.73
69DBT7E-	132.1	8.00	8	506	1433.5	46.1	820427.3	68.5	7.00	87	9.7	4195	6000	36	0.75
69DBT7E	158.0	8.00	8	506	1433.5	46.1	820427.3	68.5	7.00	87	9.7	5989	7384	52	0.75
69DBT5E-	158.1	5.33	8	342	1155.0	41.7	707991	68.5	7.00	56	9.7	4000	6000	36	0.75
69DBT5E	194.0	5.33	8	342	1155.0	41.7	707991	68.5	7.00	56	9.7	5804	7256	58	0.75
75DU15E-	64.0	16.00	8	1012	2700.8	51.5	1896714	74.6	10.30	180	9.0	4000	6000	16	0.75
75DU15E	83.0	16.00	8	1012	2700.8	51.5	1896714	74.6	10.30	180	9.0	4000	6000	24	0.75
75DU10E-	83.1	10.67	8	664	2142.8	46.7	1649631	74.6	10.30	118	9.0	4000	6000	18	0.75
75DU10E	105.0	10.67	8	664	2142.8	46.7	1649631	74.6	10.30	118	9.0	4000	6000	28	0.75
75DU7E-	105.1	8.00	8	506	1863.8	43.2	1472110	74.6	10.30	87	9.0	4000	6000	28	0.75
75DU7E	121.0	8.00	8	506	1863.8	43.2	1472110	74.6	10.30	87	9.0	4000	6000	34	0.75
10DS15S-	15.1	16.00	9	1012	1800.0	5.0	15000	10.0	180.00	180	9.0	4000	6000	20	0.66
10DS15S	20.0	16.00	9	1012	1800.0	5.0	15000	10.0	180.00	180	9.0	4000	6000	30	0.66
13DS15S-	20.1	16.00	12	1012	2367.1	6.5	33244.6	13.0	180.00	180	12.0	4000	6000	20	0.68
13DS15S	29.0	16.00	12	1012	2367.1	6.5	33244.6	13.0	180.00	180	12.0	4000	6000	40	0.68
17DS15S-	29.1	16.00	16	1012	3087.1	8.5	74092.1	17.0	180.00	180	16.0	4000	6000	30	0.70

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
17DS15S	39.0	16.00	16	1012	3087.1	8.5	74092.1	17.0	180.00	180	16.0	4000	6000	62	0.70
20DS15S-	39.1	16.00	19	1012	3600.1	10.0	120000.1	20.0	180.00	180	19.0	4000	6000	44	0.70
20DS15S	47.0	16.00	19	1012	3600.1	10.0	120000.1	20.0	180.00	180	19.0	4000	6000	68	0.70
32DU15S-	29.0	16.00	8	1012	2266.6	21.8	219173.8	32.0	10.30	180	9.0	4000	6000	12	0.69
32DU15S~	47.0	16.00	8	1012	2266.6	21.8	219173.8	32.0	10.30	180	9.0	4000	6000	30	0.69
32DU15S	65.0	16.00	8	1012	2266.6	21.8	219173.8	32.0	10.30	180	9.0	4772	6000	56	0.69
32DU10S-	65.1	10.67	8	675	1708.6	19.9	191357.1	32.0	10.30	118	9.0	4000	6000	38	0.70
32DU10S	75.0	10.67	8	675	1708.6	19.9	191357.1	32.0	10.30	118	9.0	4374	6000	52	0.70
32DU7S-	75.1	8.00	8	506	1429.6	18.4	170213.8	32.0	10.30	87	9.0	4000	6000	40	0.73
32DU7S	83.0	8.00	8	506	1429.6	18.4	170213.8	32.0	10.30	87	9.0	4360	6000	48	0.73
32DU-15S	52.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4000	6000	42	0.73
32DUC15S	66.0	16.00	8	1012	2341.3	21.6	223128.3	32.0	15.45	180	9.0	4711	6000	66	0.73
32DU-10S	66.1	10.67	8	675	1783.3	19.8	193860.1	32.0	15.45	118	9.0	4000	6000	40	0.70
32DUC10S	76.0	10.67	8	675	1783.3	19.8	193860.1	32.0	15.45	118	9.0	4243	6000	54	0.70
33DN-15S	29.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4000	6000	18	0.71
33DN~15S	44.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	4000	6000	32	0.71
33DNX15S	58.0	16.00	8	1012	2297.3	23.7	169760.2	33.0	26.00	180	9.0	5431	6000	56	0.71
33DN-10S	58.1	10.67	8	675	1739.3	22.2	149225.1	33.0	26.00	118	9.0	4078	6000	36	0.73
33DNX10S	66.0	10.67	8	675	1739.3	22.2	149225.1	33.0	26.00	118	9.0	5074	6000	46	0.73
33DNX7S-	66.1	8.00	8	506	1460.3	21.0	134165.5	33.0	26.00	87	9.0	4178	6000	36	0.73
33DNX7S	73.0	8.00	8	506	1460.3	21.0	134165.5	33.0	26.00	87	9.0	5181	6000	44	0.73
38DU15S-	29.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	12	0.66
38DU15S~	54.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	4000	6000	32	0.66
38DU15S	79.0	16.00	8	1012	2219.7	26.6	334054.2	38.0	10.30	180	9.0	5439	6000	72	0.66
38DU10S-	79.1	10.67	8	675	1661.4	24.2	294461	38.0	10.30	118	9.0	4000	6000	44	0.73
38DU10S	92.0	10.67	8	675	1661.4	24.2	294461	38.0	10.30	118	9.0	5024	6000	58	0.73
38DU7S-	92.1	8.00	8	506	1382.4	22.4	263865.4	38.0	10.30	87	9.0	4000	6000	46	0.71
38DU7S	101.0	8.00	8	506	1382.4	22.4	263865.4	38.0	10.30	87	9.0	4526	6000	54	0.71
38DU-15S	60.0	16.00	8	1012	2450.4	25.7	336250.6	38.0	15.46	180	9.0	4000	6000	38	0.75
38DUC15S	81.0	16.00	8	1012	2450.4	25.7	336250.6	38.0	15.46	180	9.0	5271	6000	64	0.75

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
38DU-10S	81.1	10.67	8	664	1892.4	23.4	288525.2	38.0	15.46	118	9.0	4000	6000	44	0.74
38DUC10S	93.0	10.67	8	664	1892.4	23.4	288525.2	38.0	15.46	118	9.0	4871	6000	60	0.74
38DUC7S-	93.1	8.00	8	506	1490.1	22.1	269229.9	38.0	15.46	87	9.0	4000	6000	46	0.73
38DUC7S	103.0	8.00	8	506	1490.1	22.1	269229.9	38.0	15.46	87	9.0	4541	6000	56	0.73
41DN-15S	62.0	16.00	8	1012	2492.0	29.6	306188.4	41.0	25.00	180	9.0	4069	6000	42	0.75
41DNX15S	75.0	16.00	8	1012	2492.0	29.6	306188.4	41.0	25.00	180	9.0	5846	6000	62	0.75
41DN-10S	75.1	10.67	8	675	1934.0	27.6	268119.6	41.0	25.00	118	9.0	4195	6000	40	0.75
41DNX10S	89.0	10.67	8	675	1934.0	27.6	268119.6	41.0	25.00	118	9.0	5983	6000	58	0.75
41DNX7S-	89.1	8.00	8	506	1655.0	26.1	240413	41.0	25.00	87	9.0	4547	6000	44	0.75
41DNX7S	99.0	8.00	8	506	1655.0	26.1	240413	41.0	25.00	87	9.0	5757	6000	56	0.75
44DU15S-	64.0	16.00	8	1012	2406.6	30.3	513364.1	44.0	10.30	180	9.0	4000	6000	36	0.74
44DU15S	94.0	16.00	8	1012	2406.6	30.3	513364.1	44.0	10.30	180	9.0	5129	6000	70	0.74
44DU10S-	94.1	10.67	8	664	1848.6	27.5	448112.5	44.0	10.30	118	9.0	4000	6000	46	0.74
44DU10S	115.0	10.67	8	664	1848.6	27.5	448112.5	44.0	10.30	118	9.0	5209	6000	70	0.74
44DU7S-	115.1	8.00	8	506	1569.6	25.4	399046.8	44.0	10.30	87	9.0	4413	6000	58	0.75
44DU7S	126.0	8.00	8	506	1569.6	25.4	399046.8	44.0	10.30	87	9.0	5252	6000	70	0.75
48DB-10S	29.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	4000	6000	6	0.74
48DB~10S	57.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	4000	6000	22	0.74
48DBT10S	85.0	10.67	8	664	1566.0	34.1	348231	47.5	7.00	118	9.7	5838	6000	40	0.74
48DBT7S-	85.1	8.00	8	506	1300.5	33.0	345263.8	47.5	7.00	87	9.7	4615	6000	30	0.75
48DBT7S	100.0	8.00	8	506	1300.5	33.0	345263.8	47.5	7.00	87	9.7	5993	6000	40	0.75
48DBT5S-	100.1	5.33	8	342	1021.5	30.3	307842.6	47.5	7.00	56	9.7	4000	6000	28	0.70
48DBT5S	124.0	5.33	8	342	1021.5	30.3	307842.6	47.5	7.00	56	9.7	5931	6000	46	0.70
51DU15S-	66.0	16.00	8	1012	2452.4	35.2	718062.3	50.6	10.30	180	9.0	4000	6000	30	0.75
51DU15S	92.0	16.00	8	1012	2452.4	35.2	718062.3	50.6	10.30	180	9.0	4585	6000	52	0.75
51DU10S-	92.1	10.67	8	664	1894.4	32.0	628472.4	50.6	10.30	118	9.0	4000	6000	38	0.75
51DU10S	119.0	10.67	8	664	1894.4	32.0	628472.4	50.6	10.30	118	9.0	5063	6000	62	0.75
51DU7S-	119.1	8.00	8	506	1615.4	29.6	561541.1	50.6	10.30	87	9.0	4220	6000	50	0.75
51DU7S	140.0	8.00	8	506	1615.4	29.6	561541.1	50.6	10.30	87	9.0	5836	6000	70	0.75
60DB-10S	68.0	10.67	8	664	1645.0	42.7	625928	59.5	7.00	118	9.7	4000	6000	22	0.75

Tabulation of girder analysis (24 page table) Part I

ID	Span (feet)	Width (feet)	Slab (inch)	Added Comp (plf)	Area (sq inch)	CG (in)	I (in^4)	Depth (inch)	Webs (inch)	Flange width (inch)	Flange Thick (inch)	F'ci req (psi)	F'c req (psi)	Strands	Jacking fract
60DBT10S	106.0	10.67	8	664	1645.0	42.7	625928	59.5	7.00	118	9.7	5893	6000	46	0.75
60DBT7S-	106.1	8.00	8	506	1370.5	40.2	572603.7	59.5	7.00	87	9.7	4569	6000	34	0.75
60DBT7S	124.0	8.00	8	506	1370.5	40.2	572603.7	59.5	7.00	87	9.7	5973	6069	46	0.75
60DBT5S-	124.1	5.33	8	342	1092.0	36.4	494112	59.5	7.00	56	9.7	4000	6000	32	0.73
60DBT5S	148.0	5.33	8	342	1092.0	36.4	494112	59.5	7.00	56	9.7	5635	6000	48	0.73
63DU15S-	70.0	16.00	8	1012	2576.9	43.5	1224488	62.6	10.30	180	9.0	4000	6000	26	0.75
63DU15S	87.0	16.00	8	1012	2576.9	43.5	1224488	62.6	10.30	180	9.0	4000	6000	38	0.75
63DU10S-	87.1	10.67	8	664	2018.9	39.5	1068904	62.6	10.30	118	9.0	4000	6000	28	0.75
63DU10S	112.0	10.67	8	664	2018.9	39.5	1068904	62.6	10.30	118	9.0	4000	6000	44	0.75
63DU7S-	112.1	8.00	8	506	1739.9	36.5	955020.1	62.6	10.30	87	9.0	4000	6000	36	0.75
63DU7S	130.0	8.00	8	506	1739.9	36.5	955020.1	62.6	10.30	87	9.0	4134	6000	46	0.75
69DB-10S	72.0	10.67	8	664	1713.0	49.0	898719	68.5	7.00	118	9.7	4000	6000	20	0.75
69DBT10S	123.0	10.67	8	664	1713.0	49.0	898719	68.5	7.00	118	9.7	5945	6062	50	0.75
69DBT7S-	123.1	8.00	8	506	1433.5	46.1	820427.3	68.5	7.00	87	9.7	4820	6000	40	0.75
69DBT7S	142.0	8.00	8	506	1433.5	46.1	820427.3	68.5	7.00	87	9.7	6007	6097	52	0.75
69DBT5S-	142.1	5.33	8	342	1155.0	41.7	707991	68.5	7.00	56	9.7	4000	6000	36	0.75
69DBT5S	170.0	5.33	8	342	1155.0	41.7	707991	68.5	7.00	56	9.7	5568	6000	52	0.75
75DU15S-	74.0	16.00	8	1012	2700.8	51.5	1896714	74.6	10.30	180	9.0	4000	6000	24	0.75
75DU15S	83.0	16.00	8	1012	2700.8	51.5	1896714	74.6	10.30	180	9.0	4000	6000	30	0.75
75DU10S-	83.1	10.67	8	664	2142.8	46.7	1649631	74.6	10.30	118	9.0	4000	6000	22	0.75
75DU10S	105.0	10.67	8	664	2142.8	46.7	1649631	74.6	10.30	118	9.0	4000	6000	32	0.75
75DU7S-	105.1	8.00	8	506	1863.8	43.2	1472110	74.6	10.30	87	9.0	4000	6000	30	0.75
75DU7S	121.0	8.00	8	506	1863.8	43.2	1472110	74.6	10.30	87	9.0	4000	6000	38	0.75

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
10DS15I-	18.1	618.7	2.30	3.34	6.4	274.1	1 HL93 43.9 INV 56.8 OPR 153.3 PERMIT	B .34 .67 .2	12.00	6	541.2
10DS15I	24.0	1005.4	2.30	3.34	9.0	393.7	1.1 HL93 45.7 INV 59.2 OPR 158 PERMIT	B .34 .67 .2	12.00	6	853.5
13DS15I-	24.1	738.2	2.30	4.34	9.0	395.9	1 HL93 44.8 INV 58 OPR 154.8 PERMIT	B .34 .67 .2	12.00	6	648.5
13DS15I	33.0	1394.4	2.30	4.34	12.4	652	1.1 HL93 46.8 INV 60.9 OPR 181.7 PERMIT	B .34 .67 .2	12.00	6	1178.4
17DS15I-	33.1	1026.5	2.30	5.67	12.4	655.6	1 HL93 44.4 INV 57.6 OPR 172.1 PERMIT	B .34 .67 .2	12.00	6	902.0
17DS15I	45.0	2053.0	2.30	5.67	16.9	1100.4	1 HL93 47.1 INV 64 OPR 146 PERMIT	B .34 .67 .2	12.00	6	1723.1
20DS15I-	45.1	1722.5	2.50	6.67	16.9	1104.2	1.1 HL93 48 INV 66.8 OPR 152.1 PERMIT	B .34 .67 .2	12.00	6	1495.7
20DS15I	56.0	2870.9	2.50	6.67	21.0	1538.6	1 HL93 48.7 INV 75.8 OPR 163.3 PERMIT	B .34 .67 .2	12.00	6	2381.9
32DU15I-	34.0	527.3	7.00	14.20	12.8	688.2	1 HL93 46.2 INV 59.9 OPR 182.3 PERMIT	B .34 .67 .2	14.00	6	461.0
32DU15I~	50.0	1054.6	7.00	14.20	19.5	1296.4	1 HL93 47.9 INV 62.1 OPR 137.3 PERMIT	B .34 .67 .2	14.00	6	888.2
32DU15I	65.0	1354.6	4.50	13.00	24.4	1915.9	1 HL93 49.9 INV 66.1 OPR 138.9 PERMIT	B .34 .67 .2	14.00	6	1096.5
32DU10I-	65.1	1054.6	4.10	12.50	24.4	1920.2	1 HL93 48.9 INV 63.4 OPR 133.1 PERMIT	B .34 .67 .2	13.00	6	873.4
32DU10I	90.0	1933.5	4.10	12.50	33.8	3050.7	1 HL93 54.1 INV 70.1 OPR 141.8 PERMIT	B .34 .67 .2	13.00	6	1491.8
32DU7I-	91.1	1669.8	4.10	11.80	34.1	3103.5	1 HL93 55.1 INV 71.5 OPR 144.3 PERMIT	B .34 .67 .2	12.00	6	1317.2
32DU7I	100.0	2021.4	4.10	11.80	37.5	3539.9	1 HL93 57 INV 73.9 OPR 145.5 PERMIT	B .34 .67 .2	12.00	6	1547.4

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
32DU-15I	48.0	966.7	7.00	14.20	18.0	1217.4	1 HL93 46.5 INV 60.2 OPR 134.7 PERMIT	B .34 .67 .2	14.00	6	819.8
32DUC15I	79.0	2460.8	7.00	14.20	29.6	2535.8	1.1 HL93 54.2 INV 71.6 OPR 146.7 PERMIT	B .34 .67 .2	14.00	6	1886.8
32DU-10I	79.1	1581.9	4.10	12.50	29.6	2540.3	1.1 HL93 54.3 INV 70.4 OPR 144.2 PERMIT	B .34 .67 .2	13.00	6	1261.8
32DUC10I	91.0	2021.4	4.10	12.50	34.5	3098.7	1 HL93 53.5 INV 70.6 OPR 142.6 PERMIT	B .34 .67 .2	13.00	6	1565.6
33DN-15I	34.0	574.2	7.80	15.7 SLEEVE 8	12.8	688.2	1.3 HL93 55.9 INV 77.2 OPR 234.9 PERMIT	B .34 .67 .2	14.22	6	489.9
33DN~15I	52.0	1066.3	7.80	15.7 SLEEVE 8	19.5	1376.3	1.1 HL93 51 INV 66.1 OPR 144.8 PERMIT	B .34 .67 .2	14.22	6	873.7
33DNX15I	70.0	1968.6	7.80	15.7 SLEEVE 8	26.3	2132.7	1 HL93 50.7 INV 80.2 OPR 166.6 PERMIT	B .34 .67 .2	14.22	6	1464.0
33DN-10I	70.1	1497.6	8.50	13.3 SLEEVE 8	26.3	2137.1	1 HL93 50.8 INV 75.2 OPR 156.2 PERMIT	B .34 .67 .2	12.83	6	1184.4
33DNX10I	80.0	1996.7	8.50	13.3 SLEEVE 8	30.0	2581.6	1 HL93 52.1 INV 81.3 OPR 166.3 PERMIT	B .34 .67 .2	12.83	6	1501.7
33DNX7I-	80.1	1539.7	7.50	12.3 SLEEVE 4	30.0	2586.1	1 HL93 52.8 INV 77.9 OPR 159.3 PERMIT	B .34 .67 .2	12.27	6	1204.6
33DNX7I	88.0	1881.9	7.50	12.3 SLEEVE 4	33.0	2955.2	1 HL93 53.4 INV 81.3 OPR 164.8 PERMIT	B .34 .67 .2	12.27	6	1424.3
38DU15I-	34.0	416.0	4.50	17.90	12.8	688.2	1.3 HL93 55.9 INV 72.5 OPR 220.4 PERMIT	B .34 .67 .2	14.00	6	361.5
38DU15I~	65.0	1164.8	4.50	17.90	24.4	1915.9	1.1 HL93 52.8 INV 68.5 OPR 143.8 PERMIT	B .34 .67 .2	14.00	6	944.3
38DU15I	96.0	2329.5	4.50	17.90	36.0	3341.8	1 HL93 54.1 INV 78.3 OPR 158.7 PERMIT	B .34 .67 .2	14.00	6	1709.2
38DU10I-	96.1	1757.7	5.00	17.30	36.0	3346.7	1 HL93 55.6 INV 72.1 OPR 146 PERMIT	B .34 .67 .2	13.00	6	1376.4

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
38DU10I	111.0	2285.0	5.00	17.30	41.6	4101.4	1 HL93 56.7 INV 73.9 OPR 136.6 PERMIT	B .34 .67 .2	13.00	6	1721.3
38DU7I-	111.1	1933.5	4.50	16.50	41.6	4106.6	1.1 HL93 60.3 INV 78.1 OPR 144.3 PERMIT	B .34 .67 .2	12.00	6	1482.4
38DU7I	123.0	2372.9	4.50	16.50	46.1	4741.7	1.1 HL93 62.4 INV 80.8 OPR 141.8 PERMIT	B .34 .67 .2	12.00	6	1752.5
38DU-15I	56.0	941.0	4.50	16.30	21.0	1538.6	1 HL93 49.6 INV 64.2 OPR 138.5 PERMIT	B .34 .67 .2	14.00	6	791.3
38DUC15I	92.0	2309.6	4.50	16.30	34.5	3146.9	1 HL93 54.2 INV 77.1 OPR 155.7 PERMIT	B .34 .67 .2	14.00	6	1760.5
38DU-10I	92.1	1710.8	4.50	17.50	34.5	3151.7	1 HL93 55.9 INV 75.7 OPR 152.8 PERMIT	B .34 .67 .2	13.00	6	1379.3
38DUC10I	113.0	2651.8	4.50	17.50	42.8	4206.1	1 HL93 57.1 INV 86.7 OPR 158.6 PERMIT	B .34 .67 .2	13.00	6	1985.3
38DUC7I-	113.1	2021.4	4.25	17.00	42.4	4211.4	1 HL93 58.7 INV 76.1 OPR 139.1 PERMIT	B .34 .67 .2	12.00	6	1576.3
38DUC7I	125.0	2548.7	4.25	17.00	46.9	4851.2	1.1 HL93 62.4 INV 82.3 OPR 143.3 PERMIT	B .34 .67 .2	12.00	6	1896.0
41DN-15I	60.0	1142.5	6.50	20 SLEEVE 16	22.5	1704.3	1 HL93 49.7 INV 74.3 OPR 158.1 PERMIT	B .34 .67 .2	14.20	6	916.7
41DNX15I	94.0	2548.7	6.50	20 SLEEVE 16	35.3	3244	1.1 HL93 56.5 INV 86.7 OPR 174.7 PERMIT	B .34 .67 .2	14.20	6	1805.4
41DN-10I	94.1	1845.6	6.50	19 SLEEVE 8	35.3	3248.8	1 HL93 53.9 INV 79.6 OPR 160.3 PERMIT	B .34 .67 .2	12.83	6	1421.2
41DNX10I	108.0	2548.7	6.50	19 SLEEVE 8	40.5	3945.9	1 HL93 57.7 INV 91.4 OPR 171.5 PERMIT	B .34 .67 .2	12.83	6	1823.5
41DNX7I-	108.1	2109.2	6.50	18.5 SLEEVE 8	40.5	3951	1 HL93 58.5 INV 91.6 OPR 171.8 PERMIT	B .34 .67 .2	12.30	6	1588.2

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
41DNX7I	120.0	2636.6	6.50	18.5 SLEEVE 8	45.0	4578.9	1 HL93 58.7 INV 96.4 OPR 171.1 PERMIT	B .34 .67 .2	12.30	6	1893.2
44DU15I-	64.0	984.3	4.25	15.00	24.0	1873.2	1.1 HL93 54.6 INV 70.7 OPR 148.9 PERMIT	B .34 .67 .2	14.00	6	823.8
44DU15I	94.0	1804.6	4.25	15.00	35.3	3244	1 HL93 54.3 INV 71.8 OPR 144.7 PERMIT	B .34 .67 .2	14.00	6	1442.0
44DU10I-	94.1	1387.4	4.50	17.50	35.3	3248.8	1 HL93 54.1 INV 70.1 OPR 141.2 PERMIT	B .34 .67 .2	13.40	6	1149.8
44DU10I	122.0	2341.3	4.50	17.50	45.8	4687.2	1 HL93 61.3 INV 83 OPR 146.1 PERMIT	B .34 .67 .2	13.40	6	1818.7
44DU7I-	122.1	2197.1	4.25	19.00	45.8	4692.6	1 HL93 61.1 INV 95.8 OPR 168.6 PERMIT	B .34 .67 .2	12.00	2	1687.5
44DU7I	144.0	3076.0	4.25	19.00	54.0	5931.6	1 HL93 62.7 INV 102 OPR 167.9 PERMIT	B .34 .67 .2	12.00	2	2213.2
48DB-10I	34.0	263.7	4.50	24.60	12.8	688.2	1.2 HL93 54 INV 70 OPR 212.8 PERMIT	B .34 .67 .2	11.30	6	227.5
48DB~10I	76.0	966.7	4.50	24.60	28.5	2399.6	1.1 HL93 54.9 INV 71.2 OPR 146.4 PERMIT	B .34 .67 .2	11.30	6	744.5
48DBT10I	117.0	2109.2	4.50	24.60	43.9	4417.9	1 HL93 59 INV 86.8 OPR 155.9 PERMIT	B .34 .67 .2	11.30	6	1375.8
48DBT7I-	117.1	1640.5	5.00	27.00	43.9	4423.3	1.1 HL93 61 INV 88.7 OPR 159.2 PERMIT	B .34 .67 .2	10.80	6	1160.2
48DBT7I	135.0	2214.7	5.00	27.00	50.6	5410.8	1 HL93 60.8 INV 97.4 OPR 164.1 PERMIT	B .34 .67 .2	10.80	6	1429.9
48DBT5I-	135.1	1625.3	6.00	24.00	50.6	5416.5	1 HL93 62.4 INV 91.6 OPR 154.4 PERMIT	B .34 .67 .2	11.10	6	1202.2
48DBT5I	154.0	2224.1	6.00	24.00	57.8	6529.4	1 HL93 64 INV 99.1 OPR 165.6 PERMIT	B .34 .67 .2	11.10	6	1504.4
51DU15I-	72.0	1054.6	4.25	16.20	27.0	2220.8	1 HL93 51.9 INV 67.3 OPR 139.4 PERMIT	B .34 .67 .2	14.00	6	879.3

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
51DU15I	92.0	1581.9	4.25	16.20	34.5	3146.9	1 HL93 54.2 INV 70.2 OPR 141.7 PERMIT	B .34 .67 .2	14.00	6	1277.3
51DU10I-	92.1	1230.4	4.25	15.00	34.5	3151.7	1.1 HL93 58.6 INV 75.9 OPR 153.3 PERMIT	B .34 .67 .2	13.00	6	1021.0
51DU10I	119.0	1845.6	4.25	15.00	43.9	4525	1 HL93 58.3 INV 75.6 OPR 134.7 PERMIT	B .34 .67 .2	13.00	6	1491.6
51DU7I-	119.1	1669.8	4.25	16.00	44.6	4530.4	1.1 HL93 65.3 INV 87.3 OPR 155.5 PERMIT	B .34 .67 .2	12.00	4	1354.1
51DU7I	140.0	2285.0	4.25	16.00	52.5	5698.2	1 HL93 64 INV 93.5 OPR 155.4 PERMIT	B .34 .67 .2	12.00	4	1784.2
60DB-10I	76.0	769.9	8.00	29.90	28.5	2399.6	1 HL93 52.6 INV 68.1 OPR 140.2 PERMIT	B .34 .67 .2	11.30	6	632.5
60DBT10I	137.0	2309.6	8.00	29.90	51.4	5525.2	1 HL93 63.4 INV 95.5 OPR 160.1 PERMIT	B .34 .67 .2	11.30	6	1583.0
60DBT7I-	137.1	1669.8	5.00	26.00	51.4	5530.9	1 HL93 61.9 INV 83.8 OPR 140.4 PERMIT	B .34 .67 .2	10.80	6	1239.8
60DBT7I	165.0	2548.7	5.00	29.00	61.9	7210	1 HL93 61.2 INV 94.3 OPR 161.1 PERMIT	B .34 .67 .2	10.80	6	1677.5
60DBT5I-	165.1	1821.0	5.00	28.00	61.9	7216.3	1 HL93 62.4 INV 94.7 OPR 161.9 PERMIT	B .34 .67 .2	11.10	6	1357.4
60DBT5I	181.0	2254.5	5.00	28.00	67.9	8243.3	1 HL93 61 INV 97 OPR 171.8 PERMIT	B .34 .67 .2	11.10	6	1592.2
63DU15I-	80.0	1054.6	4.25	18.70	30.0	2581.6	1.1 HL93 57 INV 73.9 OPR 151.1 PERMIT	B .34 .67 .2	14.00	6	885.1
63DU15I	87.0	1230.4	4.25	18.70	32.6	2907.8	1.1 HL93 59.6 INV 77.2 OPR 156.6 PERMIT	B .34 .67 .2	14.00	6	1020.0
63DU10I-	87.1	878.8	4.25	16.80	32.6	2912.5	1 HL93 54.7 INV 70.9 OPR 143.9 PERMIT	B .34 .67 .2	13.00	6	754.6
63DU10I	112.0	1406.2	4.25	16.80	42.0	4153.7	1.1 HL93 63.1 INV 81.8 OPR 150.4 PERMIT	B .34 .67 .2	13.00	6	1170.7

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
63DU7I-	112.1	1318.3	4.25	15.70	42.0	4158.9	1.2 HL93 66 INV 100.9 OPR 185.4 PERMIT	B .34 .67 .2	12.00	1	1094.8
63DU7I	130.0	1757.7	4.25	15.70	48.8	5128.5	1.1 HL93 68.5 INV 111.7 OPR 191.2 PERMIT	B .34 .67 .2	12.00	1	1418.0
69DB-10I	84.0	759.3	5.00	24.00	31.5	2766.8	1.1 HL93 57 INV 73.9 OPR 150.4 PERMIT	B .34 .67 .2	11.30	6	622.2
69DBT10I	132.0	1603.0	5.00	24.00	49.5	5240.8	1 HL93 61.1 INV 82.8 OPR 140.8 PERMIT	B .34 .67 .2	11.30	6	1211.8
69DBT7I-	132.1	1406.2	6.00	26.00	49.5	5246.5	1.1 HL93 66.3 INV 86 OPR 146.1 PERMIT	B .34 .67 .2	10.80	6	1090.6
69DBT7I	158.0	1933.5	6.00	26.00	59.3	6774.1	1 HL93 62.1 INV 87.5 OPR 147.4 PERMIT	B .34 .67 .2	10.80	6	1436.3
69DBT5I-	158.1	1406.2	5.00	28.00	59.3	6780.2	1.1 HL93 65.5 INV 90 OPR 151.6 PERMIT	B .34 .67 .2	11.10	6	1123.5
69DBT5I	196.0	2285.0	5.00	28.00	73.5	9258.6	1.1 HL93 62 INV 98.5 OPR 180.8 PERMIT	B .34 .67 .2	11.10	6	1662.7
75DU15I-	64.0	533.2	4.25	21.10	24.0	1873.2	1.1 HL93 54.9 INV 71.1 OPR 149.7 PERMIT	B .34 .67 .2	14.00	6	471.5
75DU15I	83.0	837.8	4.25	21.10	31.1	2720.2	1.2 HL93 59.9 INV 77.7 OPR 158.3 PERMIT	B .34 .67 .2	14.00	6	727.6
75DU10I-	83.1	703.1	4.25	19.10	31.1	2724.8	1.1 HL93 56.4 INV 73.1 OPR 148.9 PERMIT	B .34 .67 .2	13.00	6	612.7
75DU10I	105.0	1054.6	4.25	19.10	39.4	3792.1	1.1 HL93 60.7 INV 78.7 OPR 150.2 PERMIT	B .34 .67 .2	13.00	6	904.0
75DU7I-	105.1	1054.6	4.25	18.10	39.4	3797.2	1 HL93 57.5 INV 109 OPR 207.8 PERMIT	B .34 .67 .2	12.00	-1	894.2
75DU7I	121.0	1406.2	4.25	18.10	45.4	4632.9	1.1 HL93 66.3 INV 123.9 OPR 219 PERMIT	B .34 .67 .2	12.00	-1	1163.4
10DS15E-	16.1	618.7	2.30	3.34	7.9	240.6	1 HL93 41.5 INV 53.8 OPR 149.8 PERMIT	L .61 .82 .46	12.00	6	539.2

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
10DS15E	22.0	1082.7	2.30	3.34	8.3	351.4	1.1 HL93 45.7 INV 59.2 OPR 157.8 PERMIT	L .61 .82 .46	12.00	6	906.6
13DS15E-	22.1	796.8	2.30	4.34	8.3	353.5	1.1 HL93 47.7 INV 61.8 OPR 164.7 PERMIT	L .61 .82 .46	12.00	6	693.4
13DS15E	31.0	1434.3	2.30	4.34	11.6	580.5	1 HL93 46.1 INV 60.7 OPR 173.5 PERMIT	L .61 .82 .46	12.00	6	1199.9
17DS15E-	31.1	1148.4	3.40	5.67	11.6	584.1	1 HL93 45.8 INV 59.3 OPR 169.8 PERMIT	L .61 .82 .46	12.00	6	1007.5
17DS15E	42.0	2378.8	3.40	5.67	15.8	985.3	1 HL93 46.9 INV 66.2 OPR 154.6 PERMIT	L .61 .82 .46	12.00	6	1972.2
20DS15E-	42.1	1722.5	2.50	6.67	16.8	989.1	1.1 HL93 47.9 INV 63.6 OPR 148.5 PERMIT	L .61 .82 .46	12.00	6	1482.5
20DS15E	51.0	2706.9	2.50	6.67	19.1	1336.3	1 HL93 48.2 INV 70.6 OPR 155.4 PERMIT	L .61 .82 .46	12.00	6	2231.1
32DU15E-	31.0	513.2	6.50	14.80	11.6	580.5	1.1 HL93 48.3 INV 62.6 OPR 178.9 PERMIT	L .61 .82 .46	14.00	6	447.0
32DU15E~	44.0	941.0	6.50	14.80	16.5	1061.8	1 HL93 46.6 INV 60.5 OPR 138.9 PERMIT	L .61 .82 .46	14.00	6	790.9
32DU15E	56.0	1312.4	4.50	12.50	21.0	1538.6	1.1 HL93 51.8 INV 67.1 OPR 144.6 PERMIT	L .61 .82 .46	14.00	6	1038.9
32DU10E-	56.1	928.1	4.50	12.50	21.0	1542.7	1 HL93 47.3 INV 61.4 OPR 132.2 PERMIT	L .61 .82 .46	13.00	6	771.0
32DU10E	82.0	1940.5	4.50	12.50	30.8	2673.8	1.1 HL93 55.1 INV 71.8 OPR 146.5 PERMIT	L .61 .82 .46	13.00	6	1457.3
32DU7E-	82.1	1539.7	4.10	12.00	31.5	2678.4	1 HL93 52.1 INV 67.6 OPR 137.9 PERMIT	L .61 .82 .46	12.00	6	1207.0
32DU7E	91.0	1881.9	4.10	12.00	34.5	3098.7	1 HL93 53.5 INV 69.3 OPR 140 PERMIT	L .61 .82 .46	12.00	6	1427.8
32DU-15E	56.0	1454.2	6.50	14.80	27.0	1538.6	1 HL93 49.5 INV 64.1 OPR 138.3 PERMIT	L .61 .82 .46	14.00	6	1172.5

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
32DUC15E	72.0	2309.6	6.50	14.80	27.0	2220.8	1 HL93 52.3 INV 68.9 OPR 142.6 PERMIT	L .61 .82 .46	14.00	6	1740.0
32DU-10E	72.1	1580.8	6.00	13.50	27.0	2225.3	1 HL93 51 INV 66.1 OPR 136.7 PERMIT	L .61 .82 .46	13.00	6	1265.7
32DUC10E	83.0	2163.1	6.00	13.50	31.1	2720.2	1 HL93 53.4 INV 72.6 OPR 147.9 PERMIT	L .61 .82 .46	13.00	6	1640.4
33DN-15E	31.0	615.2	8.50	15.7 SLEEVE 8	11.6	580.5	1.3 HL93 56.2 INV 74.6 OPR 213.1 PERMIT	L .61 .82 .46	14.22	6	520.7
33DN~15E	47.0	1142.5	8.50	15.7 SLEEVE 8	17.6	1178.2	1.1 HL93 48.8 INV 63.2 OPR 142.2 PERMIT	L .61 .82 .46	14.22	6	920.6
33DNX15E	63.0	1933.5	8.50	15.7 SLEEVE 8	23.6	1830.6	1 HL93 50 INV 67.7 OPR 142.9 PERMIT	L .61 .82 .46	14.22	6	1445.0
33DN-10E	63.1	1414.4	8.50	13.3 SLEEVE 8	23.6	1834.9	1 HL93 50.4 INV 70 OPR 147.7 PERMIT	L .61 .82 .46	12.83	6	1109.9
33DNX10E	73.0	1913.5	8.50	13.3 SLEEVE 8	27.4	2265.2	1 HL93 50.6 INV 74.8 OPR 154.5 PERMIT	L .61 .82 .46	12.83	6	1422.2
33DNX7E-	73.1	1406.2	6.90	12.3 SLEEVE 4	27.4	2269.7	1 HL93 51 INV 68 OPR 140.5 PERMIT	L .61 .82 .46	12.27	6	1093.5
33DNX7E	80.0	1757.7	6.90	12.3 SLEEVE 4	30.0	2581.6	1.1 HL93 54.4 INV 74.3 OPR 152 PERMIT	L .61 .82 .46	12.27	6	1308.2
38DU15E-	31.0	386.7	4.50	13.50	11.6	580.5	1.3 HL93 56.1 INV 72.7 OPR 207.7 PERMIT	L .61 .82 .46	14.00	6	337.0
38DU15E~	54.0	928.1	4.50	13.50	20.3	1457.1	1.1 HL93 50.7 INV 65.7 OPR 142.7 PERMIT	L .61 .82 .46	14.00	6	761.4
38DU15E	77.0	1778.8	4.50	13.50	28.9	2444.8	1.1 HL93 53.9 INV 76.4 OPR 156.8 PERMIT	L .61 .82 .46	14.00	6	1326.2
38DU10E-	77.1	1331.2	5.00	16.60	28.9	2449.3	1.1 HL93 53.4 INV 69.2 OPR 142.1 PERMIT	L .61 .82 .46	13.00	6	1060.1
38DU10E	101.0	2246.3	5.00	16.60	37.9	3590	1 HL93 57.6 INV 77.7 OPR 152.1 PERMIT	L .61 .82 .46	13.00	6	1633.1

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
38DU7E-	101.1	1856.1	5.00	16.10	37.9	3595	1.1 HL93 58.3 INV 75.6 OPR 147.8 PERMIT	L .61 .82 .46	12.00	6	1405.5
38DU7E	111.0	2193.6	5.00	16.10	41.6	4101.4	1 HL93 58.5 INV 75.8 OPR 140 PERMIT	L .61 .82 .46	12.00	6	1613.0
38DU-15E	64.0	1368.7	4.50	17.00	24.0	1873.2	1 HL93 50.1 INV 65 OPR 136.8 PERMIT	L .61 .82 .46	14.00	6	1098.3
38DUC15E	89.0	2566.2	4.50	17.00	33.4	3002.8	1 HL93 54.7 INV 76.8 OPR 155.4 PERMIT	L .61 .82 .46	14.00	6	1855.1
38DU-10E	89.1	1845.6	4.50	17.20	33.4	3007.6	1 HL93 53.8 INV 69.7 OPR 141.1 PERMIT	L .61 .82 .46	13.00	6	1445.1
38DUC10E	102.0	2460.8	4.50	17.20	38.3	3640.2	1 HL93 56 INV 76.1 OPR 147.9 PERMIT	L .61 .82 .46	13.00	6	1826.6
38DUC7E-	102.1	1933.5	4.25	16.00	38.3	3645.3	1 HL93 56.7 INV 73.5 OPR 142.7 PERMIT	L .61 .82 .46	12.00	6	1478.6
38DUC7E	114.0	2372.9	4.25	16.00	42.8	4258.8	1 HL93 57.3 INV 74.3 OPR 135.3 PERMIT	L .61 .82 .46	12.00	6	1752.1
41DN-15E	68.0	1581.9	7.00	20 SLEEVE 16	25.5	2045.4	1.1 HL93 53.5 INV 69.4 OPR 144.8 PERMIT	L .61 .82 .46	14.20	6	1209.7
41DNX15E	85.0	2460.8	7.00	20 SLEEVE 16	31.9	2813.6	1.1 HL93 55.2 INV 79.9 OPR 162.4 PERMIT	L .61 .82 .46	14.20	6	1719.3
41DN-10E	85.1	1757.7	6.50	19 SLEEVE 8	31.9	2818.3	1 HL93 54.5 INV 74.8 OPR 152.1 PERMIT	L .61 .82 .46	12.83	6	1328.7
41DNX10E	98.0	2372.9	6.50	19 SLEEVE 8	36.8	3440.5	1 HL93 55.5 INV 82.4 OPR 164.5 PERMIT	L .61 .82 .46	12.83	6	1680.9
41DNX7E-	98.1	1933.5	6.50	18.5 SLEEVE 8	36.8	3445.4	1 HL93 55.8 INV 81.6 OPR 162.8 PERMIT	L .61 .82 .46	12.30	6	1448.5
41DNX7E	109.0	2460.8	6.50	18.5 SLEEVE 8	40.9	3997.5	1 HL93 58.2 INV 88.4 OPR 165 PERMIT	L .61 .82 .46	12.30	6	1741.4

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
44DU15E-	68.0	1283.1	4.50	16.20	25.5	2045.4	1.1 HL93 51.8 INV 67.1 OPR 140 PERMIT	L .61 .82 .46	14.00	6	1036.3
44DU15E	94.0	2224.1	4.50	16.20	35.3	3244	1 HL93 56.2 INV 72.8 OPR 146.7 PERMIT	L .61 .82 .46	14.00	6	1672.5
44DU10E-	94.1	1647.6	4.50	20.20	35.3	3248.8	1.1 HL93 56.7 INV 73.5 OPR 148 PERMIT	L .61 .82 .46	13.40	6	1311.2
44DU10E	122.0	2688.1	4.50	20.20	45.8	4687.2	1 HL93 59.8 INV 80.7 OPR 142 PERMIT	L .61 .82 .46	13.40	6	1980.3
44DU7E-	122.1	2285.0	4.25	19.00	45.8	4692.6	1 HL93 61.1 INV 79.1 OPR 139.3 PERMIT	L .61 .82 .46	12.00	6	1736.2
44DU7E	139.0	2988.1	4.25	19.00	52.1	5640.3	1 HL93 63.6 INV 83.5 OPR 139.2 PERMIT	L .61 .82 .46	12.00	6	2150.5
48DB-10E	31.0	263.7	4.00	25.20	11.6	580.5	1.2 HL93 54.8 INV 71.1 OPR 203.1 PERMIT	L .61 .82 .46	11.30	6	226.3
48DB~10E	67.0	878.8	4.00	25.20	25.1	2002	1 HL93 50.6 INV 65.5 OPR 137 PERMIT	L .61 .82 .46	11.30	6	673.6
48DBT10E	103.0	1845.6	4.00	25.20	38.6	3690.7	1 HL93 55.4 INV 76.1 OPR 146.9 PERMIT	L .61 .82 .46	11.30	6	1209.8
48DBT7E-	103.1	1454.2	5.00	27.00	38.6	3695.7	1 HL93 56.8 INV 73.6 OPR 142.2 PERMIT	L .61 .82 .46	10.80	6	1041.4
48DBT7E	119.0	1967.5	5.00	27.00	45.0	4525	1 HL93 58.6 INV 81.8 OPR 145.8 PERMIT	L .61 .82 .46	10.80	6	1293.0
48DBT5E-	119.1	1368.7	6.00	26.00	44.6	4530.4	1 HL93 58.7 INV 76.1 OPR 135.5 PERMIT	L .61 .82 .46	11.10	6	1028.3
48DBT5E	146.0	2224.1	6.00	26.00	54.8	6049.6	1.1 HL93 66.7 INV 91.9 OPR 151.2 PERMIT	L .61 .82 .46	11.10	6	1453.6
51DU15E-	84.0	1581.9	4.25	16.20	27.8	2766.8	1 HL93 53.4 INV 69.2 OPR 140.8 PERMIT	L .61 .82 .46	14.00	6	1250.3
51DU15E	92.0	1845.6	4.25	16.20	34.5	3146.9	1 HL93 54.7 INV 70.9 OPR 143 PERMIT	L .61 .82 .46	14.00	6	1430.8

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
51DU10E-	92.1	1406.2	4.25	15.00	34.5	3151.7	1.1 HL93 57.5 INV 74.5 OPR 150.3 PERMIT	L .61 .82 .46	13.00	6	1135.5
51DU10E	119.0	2197.1	4.25	15.00	43.9	4525	1.1 HL93 61.9 INV 80.2 OPR 142.9 PERMIT	L .61 .82 .46	13.00	6	1684.0
51DU7E-	119.1	1845.6	4.25	17.50	44.6	4530.4	1.1 HL93 62.3 INV 80.8 OPR 143.8 PERMIT	L .61 .82 .46	12.00	6	1457.6
51DU7E	140.0	2460.8	4.25	17.50	52.5	5698.2	1 HL93 63.3 INV 82.1 OPR 136.4 PERMIT	L .61 .82 .46	12.00	6	1874.9
60DB-10E	64.0	703.1	8.00	31.00	24.0	1873.2	1.1 HL93 51.2 INV 66.4 OPR 139.7 PERMIT	L .61 .82 .46	11.30	6	573.9
60DBT10E	130.0	2372.9	8.00	31.00	48.8	5128.5	1 HL93 60.3 INV 84.1 OPR 143.9 PERMIT	L .61 .82 .46	11.30	6	1576.7
60DBT7E-	130.1	1796.4	6.00	26.80	44.6	5134.1	1 HL93 61.4 INV 85.3 OPR 146 PERMIT	L .61 .82 .46	10.80	6	1273.0
60DBT7E	146.0	2285.0	6.00	26.50	54.8	6049.6	1 HL93 62.6 INV 87.4 OPR 143.9 PERMIT	L .61 .82 .46	10.80	6	1523.8
60DBT5E-	146.1	1581.9	4.50	27.00	55.5	6055.5	1.1 HL93 65.7 INV 89.1 OPR 146.6 PERMIT	L .61 .82 .46	11.10	6	1177.2
60DBT5E	168.0	2197.1	4.50	27.00	63.0	7399.8	1.1 HL93 65.1 INV 96.5 OPR 166 PERMIT	L .61 .82 .46	11.10	6	1496.5
63DU15E-	68.0	878.8	4.25	18.70	25.5	2045.4	1 HL93 49.7 INV 64.4 OPR 134.3 PERMIT	L .61 .82 .46	14.00	6	741.8
63DU15E	87.0	1406.2	4.25	18.70	32.6	2907.8	1.1 HL93 58.1 INV 75.3 OPR 152.7 PERMIT	L .61 .82 .46	14.00	6	1136.3
63DU10E-	87.1	1054.6	4.25	16.80	32.6	2912.5	1.1 HL93 59 INV 76.5 OPR 155.2 PERMIT	L .61 .82 .46	13.00	6	882.0
63DU10E	112.0	1581.9	4.25	16.80	42.0	4153.7	1.1 HL93 60.9 INV 79 OPR 145.2 PERMIT	L .61 .82 .46	13.00	6	1284.4
63DU7E-	112.1	1406.2	4.25	15.70	42.0	4158.9	1 HL93 58.2 INV 88.4 OPR 162.5 PERMIT	L .61 .82 .46	12.00	1	1154.0

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
63DU7E	130.0	1933.5	4.25	15.70	48.8	5128.5	1.1 HL93 64.8 INV 103.1 OPR 176.4 PERMIT	L .61 .82 .46	12.00	1	1521.0
69DB-10E	72.0	684.3	5.00	30.50	27.0	2220.8	1.1 HL93 53.3 INV 69.1 OPR 143 PERMIT	L .61 .82 .46	11.30	6	558.6
69DBT10E	132.0	1881.9	5.00	30.50	49.5	5240.8	1 HL93 60.4 INV 82.7 OPR 140.6 PERMIT	L .61 .82 .46	11.30	6	1328.3
69DBT7E-	132.1	1581.9	6.00	27.20	49.5	5246.5	1.1 HL93 63.4 INV 82.1 OPR 139.6 PERMIT	L .61 .82 .46	10.80	6	1178.8
69DBT7E	158.0	2285.0	6.00	27.20	59.3	6774.1	1.1 HL93 64.6 INV 89.5 OPR 150.8 PERMIT	L .61 .82 .46	10.80	6	1564.5
69DBT5E-	158.1	1581.9	5.00	30.40	57.8	6780.2	1 HL93 63.7 INV 87.2 OPR 146.9 PERMIT	L .61 .82 .46	11.10	6	1212.5
69DBT5E	194.0	2548.7	5.00	30.40	72.8	9120.6	1.1 HL93 62.3 INV 98.4 OPR 179.7 PERMIT	L .61 .82 .46	11.10	6	1730.0
75DU15E-	64.0	703.1	4.25	21.10	24.0	1873.2	1.1 HL93 53.4 INV 69.2 OPR 145.7 PERMIT	L .61 .82 .46	14.00	6	603.7
75DU15E	83.0	1054.6	4.25	21.10	31.1	2720.2	1 HL93 54.1 INV 70.1 OPR 142.9 PERMIT	L .61 .82 .46	14.00	6	886.1
75DU10E-	83.1	791.0	4.25	19.10	31.1	2724.8	1.1 HL93 54.5 INV 70.6 OPR 143.9 PERMIT	L .61 .82 .46	13.00	6	681.1
75DU10E	105.0	1230.4	4.25	19.10	39.4	3792.1	1.1 HL93 63.1 INV 81.8 OPR 156.2 PERMIT	L .61 .82 .46	13.00	6	1029.3
75DU7E-	105.1	1230.4	4.25	18.10	39.4	3797.2	1.2 HL93 66.2 INV 111.4 OPR 212.5 PERMIT	L .61 .82 .46	12.00	-1	1017.3
75DU7E	121.0	1494.0	4.25	18.10	45.4	4632.9	1 HL93 59.1 INV 108.1 OPR 191.1 PERMIT	L .61 .82 .46	12.00	-1	1222.2
10DS15S-	15.1	773.4	2.30	3.34	7.5	224.1	1.1 HL93 44.4 INV 57.5 OPR 163 PERMIT	N 1 1 1	12.00	6	661.8
10DS15S	20.0	1160.1	2.30	3.34	7.9	310	1 HL93 44 INV 57 OPR 152 PERMIT	N 1 1 1	12.00	6	960.4

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
13DS15S-	20.1	796.8	2.30	4.34	7.5	312.1	1 HL93 43.3 INV 56.1 OPR 149.5 PERMIT	N 1 1 1	12.00	6	691.7
13DS15S	29.0	1593.6	2.30	4.34	10.9	510	1 HL93 46.2 INV 61.4 OPR 166.4 PERMIT	N 1 1 1	12.00	6	1308.4
17DS15S-	29.1	1230.4	3.40	5.67	10.9	513.5	1 HL93 45.5 INV 58.9 OPR 160.2 PERMIT	N 1 1 1	12.00	6	1070.9
17DS15S	39.0	2542.8	3.40	5.67	14.6	872.2	1 HL93 46.3 INV 64.6 OPR 155.8 PERMIT	N 1 1 1	12.00	6	2073.3
20DS15S-	39.1	1804.6	2.50	6.67	14.6	875.9	1 HL93 46.8 INV 61.7 OPR 148.7 PERMIT	N 1 1 1	12.00	6	1534.3
20DS15S	47.0	2788.9	2.50	6.67	17.6	1178.2	1 HL93 46.6 INV 67.2 OPR 151.2 PERMIT	N 1 1 1	12.00	6	2260.9
32DU15S-	29.0	485.1	5.40	12.50	10.9	510	1 HL93 46.2 INV 59.9 OPR 162.4 PERMIT	N 1 1 1	14.00	6	420.6
32DU15S~	47.0	1212.8	5.40	12.50	17.6	1178.2	1.1 HL93 49 INV 63.5 OPR 142.9 PERMIT	N 1 1 1	14.00	6	968.0
32DU15S	65.0	2263.9	5.40	12.50	24.4	1915.9	1 HL93 50.8 INV 71.6 OPR 150.4 PERMIT	N 1 1 1	14.00	6	1610.2
32DU10S-	65.1	1558.5	5.30	12.50	24.4	1920.2	1 HL93 50.2 INV 65.1 OPR 136.7 PERMIT	N 1 1 1	13.00	6	1206.6
32DU10S	75.0	2132.7	5.30	12.50	28.1	2354.6	1.1 HL93 53 INV 71.2 OPR 146.6 PERMIT	N 1 1 1	13.00	6	1546.3
32DU7S-	75.1	1710.8	4.10	12.50	28.1	2359.1	1.1 HL93 54.1 INV 70.2 OPR 144.6 PERMIT	N 1 1 1	12.00	6	1279.2
32DU7S	83.0	2053.0	4.10	12.50	32.0	2720.2	1 HL93 54.3 INV 70.4 OPR 143.4 PERMIT	N 1 1 1	12.00	6	1481.3
32DU-15S	52.0	1796.4	9.00	15.00	19.5	1376.3	1 HL93 48.3 INV 62.6 OPR 137.1 PERMIT	N 1 1 1	14.00	6	1431.1
32DUC15S	66.0	2822.9	9.00	15.00	24.8	1958.9	1 HL93 50.2 INV 65.9 OPR 138 PERMIT	N 1 1 1	14.00	6	2089.7

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
32DU-10S	66.1	1640.5	5.50	13.00	25.5	1963.2	1 HL93 50.4 INV 65.3 OPR 136.8 PERMIT	N 1 1 1	13.00	6	1274.7
32DUC10S	76.0	2214.7	5.50	13.00	28.5	2399.6	1 HL93 51.3 INV 70.2 OPR 144.4 PERMIT	N 1 1 1	13.00	6	1620.3
33DN-15S	29.0	748.8	10.60	15.8 SLEEVE 12	10.9	510	1.3 HL93 58.4 INV 82.4 OPR 223.4 PERMIT	N 1 1 1	14.22	6	631.5
33DN~15S	44.0	1331.2	10.60	15.8 SLEEVE 12	16.5	1061.8	1.1 HL93 48.6 INV 63 OPR 144.7 PERMIT	N 1 1 1	14.22	6	1068.8
33DNX15S	58.0	2329.5	10.60	15.8 SLEEVE 12	21.8	1621	1 HL93 47.7 INV 70.1 OPR 150.2 PERMIT	N 1 1 1	14.22	6	1700.7
33DN-10S	58.1	1539.7	8.50	13.3 SLEEVE 8	21.8	1625.2	1.1 HL93 50.7 INV 66.9 OPR 143.2 PERMIT	N 1 1 1	12.83	6	1172.8
33DNX10S	66.0	1967.5	8.50	13.3 SLEEVE 8	24.8	1958.9	1 HL93 49.3 INV 68.6 OPR 143.8 PERMIT	N 1 1 1	12.83	6	1431.9
33DNX7S-	66.1	1539.7	8.00	12.3 SLEEVE 4	24.8	1963.2	1 HL93 50.8 INV 68.4 OPR 143.4 PERMIT	N 1 1 1	12.27	6	1169.2
33DNX7S	73.0	1881.9	8.00	12.3 SLEEVE 4	27.4	2265.2	1 HL93 50.4 INV 70.2 OPR 145.2 PERMIT	N 1 1 1	12.27	6	1376.1
38DU15S-	29.0	464.0	7.80	16.50	10.9	510	1.3 HL93 55.7 INV 72.1 OPR 195.5 PERMIT	N 1 1 1	14.00	6	404.3
38DU15S~	54.0	1237.4	7.80	16.50	20.3	1457.1	1 HL93 47.5 INV 61.6 OPR 133.8 PERMIT	N 1 1 1	14.00	6	999.8
38DU15S	79.0	2784.2	7.80	16.50	29.6	2535.8	1 HL93 52.8 INV 80.8 OPR 165.5 PERMIT	N 1 1 1	14.00	6	1901.2
38DU10S-	79.1	1881.9	6.00	15.40	29.6	2540.3	1.1 HL93 54.2 INV 70.2 OPR 143.9 PERMIT	N 1 1 1	13.00	6	1401.0

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
38DU10S	92.0	2480.7	6.00	15.40	34.5	3146.9	1 HL93 55.4 INV 71.9 OPR 145.1 PERMIT	N 1 1 1	13.00	6	1745.7
38DU7S-	92.1	1913.5	5.00	15.50	34.5	3151.7	1 HL93 55.7 INV 72.2 OPR 145.7 PERMIT	N 1 1 1	12.00	6	1404.9
38DU7S	101.0	2246.3	5.00	15.50	37.9	3590	1 HL93 55.1 INV 71.7 OPR 140.2 PERMIT	N 1 1 1	12.00	6	1598.6
38DU-15S	60.0	1669.8	5.50	16.50	22.5	1704.3	1.1 HL93 52 INV 67.4 OPR 143.5 PERMIT	N 1 1 1	14.00	6	1288.0
38DUC15S	81.0	2812.3	5.50	16.50	30.4	2627.6	1 HL93 53.2 INV 71 OPR 145 PERMIT	N 1 1 1	14.00	6	1972.8
38DU-10S	81.1	1907.7	4.50	15.50	30.4	2632.2	1 HL93 52.3 INV 67.8 OPR 138.4 PERMIT	N 1 1 1	13.00	6	1449.0
38DUC10S	93.0	2601.4	4.50	15.50	34.1	3195.3	1 HL93 56 INV 75.7 OPR 152.6 PERMIT	N 1 1 1	13.00	6	1842.2
38DUC7S-	93.1	1967.5	4.25	17.50	34.9	3200.2	1 HL93 54.5 INV 70.7 OPR 142.5 PERMIT	N 1 1 1	12.00	6	1461.8
38DUC7S	103.0	2395.2	4.25	17.50	38.6	3690.7	1 HL93 55.7 INV 72.2 OPR 139.5 PERMIT	N 1 1 1	12.00	6	1708.1
41DN-15S	62.0	1845.6	10.80	18.9 SLEEVE 8	23.3	1788.3	1 HL93 49.9 INV 64.6 OPR 136.7 PERMIT	N 1 1 1	14.20	6	1416.7
41DNX15S	75.0	2724.4	10.80	18.9 SLEEVE 8	28.1	2354.6	1 HL93 51.1 INV 72.1 OPR 148.6 PERMIT	N 1 1 1	14.20	6	1936.2
41DN-10S	75.1	1757.7	7.60	17.3 SLEEVE 8	28.1	2359.1	1 HL93 52.1 INV 69.1 OPR 142.4 PERMIT	N 1 1 1	12.83	6	1316.5
41DNX10S	89.0	2548.7	7.60	17.3 SLEEVE 8	33.4	3002.8	1 HL93 53.9 INV 77.9 OPR 157.8 PERMIT	N 1 1 1	12.83	6	1746.3
41DNX7S-	89.1	1933.5	6.50	17 SLEEVE 8	33.4	3007.6	1 HL93 53.3 INV 75.2 OPR 152.2 PERMIT	N 1 1 1	12.30	6	1413.1
41DNX7S	99.0	2460.8	6.50	17 SLEEVE 8	37.1	3490.1	1 HL93 55.3 INV 81.3 OPR 161.2 PERMIT	N 1 1 1	12.30	6	1687.6

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
44DU15S-	64.0	1560.8	7.00	18.40	24.0	1873.2	1 HL93 51 INV 66.1 OPR 139.2 PERMIT	N 1 1 1	14.00	6	1233.7
44DU15S	94.0	3035.0	7.00	18.40	35.3	3244	1 HL93 54 INV 71.7 OPR 144.5 PERMIT	N 1 1 1	14.00	6	2143.5
44DU10S-	94.1	1994.4	4.50	19.00	35.3	3248.8	1 HL93 54.2 INV 70.3 OPR 141.6 PERMIT	N 1 1 1	13.40	6	1513.6
44DU10S	115.0	3035.0	4.50	19.00	43.1	4311.6	1 HL93 58.8 INV 79.3 OPR 143.7 PERMIT	N 1 1 1	13.40	6	2095.5
44DU7S-	115.1	2548.7	4.25	19.00	43.1	4316.9	1 HL93 59.7 INV 77.3 OPR 140.1 PERMIT	N 1 1 1	12.00	6	1834.9
44DU7S	126.0	3076.0	4.25	19.00	47.3	4906.2	1 HL93 61.8 INV 80.1 OPR 139 PERMIT	N 1 1 1	12.00	6	2112.7
48DB-10S	29.0	260.1	7.10	24.00	10.9	510	1 HL93 44.8 INV 58.1 OPR 157.4 PERMIT	N 1 1 1	11.30	6	225.8
48DB~10S	57.0	953.8	7.10	24.00	21.4	1579.7	1.1 HL93 54.2 INV 70.2 OPR 150.8 PERMIT	N 1 1 1	11.30	6	725.0
48DBT10S	85.0	1734.3	7.10	24.00	31.9	2813.6	1 HL93 53.1 INV 69.3 OPR 140.9 PERMIT	N 1 1 1	11.30	6	1177.3
48DBT7S-	85.1	1318.3	5.00	25.00	34.9	2818.3	1 HL93 53 INV 68.7 OPR 139.6 PERMIT	N 1 1 1	10.80	6	939.4
48DBT7S	100.0	1757.7	5.00	25.00	37.5	3539.9	1 HL93 55.5 INV 72 OPR 141.8 PERMIT	N 1 1 1	10.80	6	1165.6
48DBT5S-	100.1	1148.4	5.00	22.00	46.5	3544.9	1 HL93 56 INV 72.5 OPR 142.8 PERMIT	N 1 1 1	11.10	6	860.5
48DBT5S	124.0	1886.6	5.00	22.00	46.5	4796.3	1 HL93 61.5 INV 87.4 OPR 152.7 PERMIT	N 1 1 1	11.10	6	1227.3
51DU15S-	66.0	1318.3	4.25	16.20	24.8	1958.9	1 HL93 51.1 INV 66.3 OPR 138.8 PERMIT	N 1 1 1	14.00	6	1045.4
51DU15S	92.0	2285.0	4.25	16.20	34.5	3146.9	1 HL93 54.2 INV 70.2 OPR 141.8 PERMIT	N 1 1 1	14.00	6	1670.9

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
51DU10S-	92.1	1669.8	4.25	18.00	34.5	3151.7	1 HL93 54.1 INV 70.1 OPR 141.6 PERMIT	N 1 1 1	13.00	6	1301.2
51DU10S	119.0	2724.4	4.25	18.00	43.9	4525	1.1 HL93 61.2 INV 79.4 OPR 141.4 PERMIT	N 1 1 1	13.00	6	1943.3
51DU7S-	119.1	2197.1	4.25	17.00	44.6	4530.4	1 HL93 58.1 INV 75.4 OPR 134.2 PERMIT	N 1 1 1	12.00	6	1655.6
51DU7S	140.0	3076.0	4.25	17.00	52.5	5698.2	1 HL93 62.3 INV 81.7 OPR 135.8 PERMIT	N 1 1 1	12.00	6	2155.1
60DB-10S	68.0	966.7	8.00	29.00	25.5	2045.4	1.1 HL93 52.5 INV 68 OPR 141.9 PERMIT	N 1 1 1	11.30	6	749.7
60DBT10S	106.0	2021.4	8.00	29.00	39.8	3843.2	1 HL93 58.3 INV 75.8 OPR 143.8 PERMIT	N 1 1 1	11.30	6	1359.2
60DBT7S-	106.1	1494.0	5.00	23.00	39.8	3848.3	1 HL93 56.9 INV 73.7 OPR 139.8 PERMIT	N 1 1 1	10.80	6	1064.8
60DBT7S	124.0	2021.4	5.00	23.00	46.5	4796.3	1 HL93 59.3 INV 81.1 OPR 141.7 PERMIT	N 1 1 1	10.80	6	1329.7
60DBT5S-	124.1	1368.7	4.50	26.00	46.5	4801.8	1 HL93 61.1 INV 81.2 OPR 141.8 PERMIT	N 1 1 1	11.10	6	1017.2
60DBT5S	148.0	2053.0	4.50	26.00	55.5	6168.3	1 HL93 64.4 INV 95.2 OPR 157.3 PERMIT	N 1 1 1	11.10	6	1365.1
63DU15S-	70.0	1142.5	4.25	18.70	26.3	2132.7	1 HL93 50.3 INV 65.2 OPR 135.5 PERMIT	N 1 1 1	14.00	6	933.6
63DU15S	87.0	1669.8	4.25	18.70	32.6	2907.8	1 HL93 54.2 INV 70.3 OPR 142.6 PERMIT	N 1 1 1	14.00	6	1305.4
63DU10S-	87.1	1230.4	4.25	16.80	32.6	2912.5	1 HL93 54.6 INV 70.8 OPR 143.5 PERMIT	N 1 1 1	13.00	6	1006.5
63DU10S	112.0	1933.5	4.25	16.80	42.0	4153.7	1.1 HL93 60.9 INV 78.9 OPR 145 PERMIT	N 1 1 1	13.00	6	1498.9
63DU7S-	112.1	1581.9	4.25	15.70	42.0	4158.9	1 HL93 59.5 INV 77.1 OPR 141.6 PERMIT	N 1 1 1	12.00	6	1272.1

Tabulation of girder analysis (24 page table) Part II

ID	Span (feet)	Pjack (k)	Ems (inch)	EE (inch)	Harp (feet)	LL+I /Lane	Rating	Comp Fixity adj	Dist (feet)	Ser III sqrt (f'c)	Final force (k)
63DU7S	130.0	2021.4	4.25	15.70	48.8	5128.5	1 HL93 60 INV 77.8 OPR 133.2 PERMIT	N 1 1 1	12.00	6	1585.6
69DB-10S	72.0	878.8	6.90	27.40	27.0	2220.8	1 HL93 52 INV 67.4 OPR 139.6 PERMIT	N 1 1 1	11.30	6	694.2
69DBT10S	123.0	2197.1	6.90	27.40	46.1	4741.7	1 HL93 60.4 INV 81 OPR 142.1 PERMIT	N 1 1 1	11.30	6	1457.5
69DBT7S-	123.1	1757.7	6.00	28.00	46.1	4747.1	1.1 HL93 64 INV 82.9 OPR 145.3 PERMIT	N 1 1 1	10.80	6	1236.8
69DBT7S	142.0	2285.0	6.00	28.00	53.3	5814.5	1 HL93 62.7 INV 88.4 OPR 146.2 PERMIT	N 1 1 1	10.80	6	1502.4
69DBT5S-	142.1	1581.9	4.50	30.00	55.3	5820.3	1.1 HL93 68 INV 89.2 OPR 147.5 PERMIT	N 1 1 1	11.10	6	1164.0
69DBT5S	170.0	2285.0	4.50	30.00	63.8	7527.4	1 HL93 60.4 INV 89.7 OPR 155 PERMIT	N 1 1 1	11.10	6	1537.4
75DU15S-	74.0	1054.6	4.25	21.10	27.8	2309.8	1 HL93 51.3 INV 66.5 OPR 137.2 PERMIT	N 1 1 1	14.00	6	876.7
75DU15S	83.0	1318.3	4.25	21.10	31.1	2720.2	1.1 HL93 55.6 INV 72.1 OPR 146.9 PERMIT	N 1 1 1	14.00	6	1071.5
75DU10S-	83.1	966.7	4.25	19.10	31.1	2724.8	1.1 HL93 55.2 INV 71.5 OPR 145.7 PERMIT	N 1 1 1	13.00	6	814.2
75DU10S	105.0	1406.2	4.25	19.10	39.4	3792.1	1 HL93 56.3 INV 73 OPR 139.4 PERMIT	N 1 1 1	13.00	6	1153.6
75DU7S-	105.1	1318.3	4.25	18.10	39.4	3797.2	1.2 HL93 64.9 INV 91.1 OPR 173.8 PERMIT	N 1 1 1	12.00	1	1081.4
75DU7S	121.0	1669.8	4.25	18.10	45.4	4632.9	1.1 HL93 62 INV 94.3 OPR 166.7 PERMIT	N 1 1 1	12.00	1	1339.6

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
10DS15I-	18.1	1.96	0.1	0.0	1.54	33.9	190.3	57.5	380.6		
10DS15I	24.0	1.07	0.3	0.0	1.74	45.0	240.0	50.0	480.0		
13DS15I-	24.1	2.29	0.1	0.0	1.44	59.4	250.2	55.4	500.4		
13DS15I	33.0	1.05	0.4	0.1	1.69	81.4	308.5	48.9	617.0		
17DS15I-	33.1	2.27	0.1	0.0	1.44	106.4	325.6	55.9	651.2		
17DS15I	45.0	1.04	0.5	0.1	1.66	144.7	391.3	51.0	782.6		
20DS15I-	45.1	1.65	0.1	0.1	1.63	169.1	407.9	56.0	815.8		
20DS15I	56.0	1.00	0.5	0.2	1.74	210.0	464.1	53.3	928.2		
32DU15I-	34.0	7.00	0.1	0.0	1.11	82.9	278.9	47.1	557.8		
32DU15I~	50.0	2.68	0.4	0.0	1.40	121.9	349.3	41.4	698.6		
32DU15I	65.0	1.48	0.9	0.1	1.65	153.5	402.7	37.8	805.4		
32DU10I-	65.1	1.99	0.7	0.1	1.44	115.9	291.1	40.9	873.3		
32DU10I	90.0	1.02	1.8	0.4	1.58	160.2	352.8	38.2	1058.4		
32DU7I-	91.1	1.21	1.2	0.4	1.54	135.7	288.9	41.2	1155.6		
32DU7I	100.0	1.01	1.5	0.5	1.56	148.9	306.1	40.6	1224.4		
32DU-15I	48.0	2.94	0.4	0.0	1.37	117.1	341.3	41.9	682.6		
32DUC15I	79.0	1.01	1.9	0.3	1.64	192.7	455.2	36.8	910.4		
32DU-10I	79.1	1.35	1.2	0.2	1.55	146.9	330.1	40.2	990.3		
32DUC10I	91.0	1.02	1.7	0.4	1.59	169.0	359.6	39.2	1078.8		
33DN-15I	34.0	5.32	0.2	0.0	1.40	81.4	274.8	46.7	549.6		
33DN~15I	52.0	1.87	0.6	0.1	1.65	124.4	352.0	40.5	704.0		
33DNX15I	70.0	1.00	1.9	0.2	1.84	167.5	417.7	37.4	835.4		
33DN-10I	70.1	1.33	1.3	0.2	1.75	127.0	307.8	40.7	923.4		
33DNX10I	80.0	1.01	2.1	0.3	1.79	144.9	332.7	39.6	998.1		
33DNX7I-	80.1	1.23	1.6	0.3	1.71	121.8	265.3	42.7	1061.2		
33DNX7I	88.0	1.02	2.1	0.4	1.73	133.9	281.0	42.0	1124.0		
38DU15I-	34.0	10.32	0.1	0.0	1.07	78.6	276.2	46.0	552.4		
38DU15I~	65.0	2.21	0.8	0.1	1.49	150.3	400.8	37.4	801.6		
38DU15I	96.0	1.01	2.4	0.4	1.70	222.0	505.0	34.3	1010.0		
38DU10I-	96.1	1.34	1.4	0.3	1.53	166.3	364.4	37.1	1093.2		

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
38DU10I	111.0	1.01	1.9	0.6	1.57	192.1	399.0	36.2	1197.0		
38DU7I-	111.1	1.24	1.2	0.5	1.53	160.0	323.9	39.1	1295.6		
38DU7I	123.0	1.02	1.5	0.8	1.55	177.1	346.0	38.5	1384.0		
38DU-15I	56.0	3.18	0.4	0.0	1.38	142.9	376.6	38.5	753.2		
38DUC15I	92.0	1.14	2	0.3	1.66	234.8	505.8	36.7	1011.6		
38DU-10I	92.1	1.50	0.9	0.3	1.60	181.6	368.1	40.4	1104.3		
38DUC10I	113.0	1.01	1.7	0.6	1.67	222.8	419.8	39.1	1259.4		
38DUC7I-	113.1	1.23	0.7	0.6	1.54	175.6	335.6	40.9	1342.4		
38DUC7I	125.0	1.02	1.1	0.8	1.56	194.0	358.5	40.4	1434.0		
41DN-15I	60.0	2.49	0.7	0.1	1.51	155.8	390.0	40.7	780.0		
41DNX15I	94.0	1.00	2.7	0.4	1.75	244.0	511.0	36.9	1022.0		
41DN-10I	94.1	1.32	1.7	0.3	1.67	189.6	379.2	41.0	1137.6		
41DNX10I	108.0	1.02	2.9	0.6	1.73	217.6	414.2	40.1	1242.6		
41DNX7I-	108.1	1.23	1.9	0.5	1.69	186.4	333.2	44.2	1332.8		
41DNX7I	120.0	1.01	2.6	0.8	1.71	206.9	357.3	43.6	1429.2		
44DU15I-	64.0	3.53	0.5	0.1	1.38	160.4	405.0	39.3	810.0		
44DU15I	94.0	1.60	1.4	0.2	1.59	235.6	509.9	36.1	1019.8		
44DU10I-	94.1	2.14	0.6	0.2	1.45	181.2	364.2	39.6	1092.6		
44DU10I	122.0	1.29	1.4	0.6	1.57	234.9	431.3	38.0	1293.9		
44DU7I-	122.1	1.57	1.1	0.5	1.54	199.6	359.2	41.9	1436.8		
44DU7I	144.0	1.15	1.4	1.0	1.57	235.4	402.1	41.1	1608.4		
48DB-10I	34.0	16.19	0.1	0.0	1.00	55.5	218.3	48.1	654.9		
48DB~10I	76.0	2.49	1.2	0.1	1.50	124.0	340.3	37.8	1020.9		
48DBT10I	117.0	1.09	3.9	0.6	1.74	190.9	438.6	34.7	1315.8		
48DBT7I-	117.1	1.39	2.5	0.5	1.71	158.6	349.2	37.4	1396.8		
48DBT7I	135.0	1.08	3.6	0.8	1.78	182.9	382.4	36.7	1529.6		
48DBT5I-	135.1	1.32	1.4	0.8	1.64	141.9	265.3	41.1	1591.8		
48DBT5I	154.0	1.01	2.2	1.4	1.68	161.7	290.1	40.5	1740.6		
51DU15I-	72.0	3.83	0.6	0.1	1.30	183.9	436.0	38.6	872.0		
51DU15I	92.0	2.31	1.2	0.2	1.43	235.0	505.9	36.7	1011.8		

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
51DU10I-	92.1	3.11	0.8	0.1	1.37	181.7	368.3	40.5	1104.9		
51DU10I	119.0	1.86	1.2	0.4	1.48	234.8	434.5	38.9	1303.5		
51DU7I-	119.1	2.27	0.8	0.3	1.47	200.4	356.9	42.9	1427.6		
51DU7I	140.0	1.66	1.1	0.6	1.53	235.6	398.5	42.1	1594.0		
60DB-10I	76.0	4.44	0.6	0.1	1.38	130.2	344.2	38.8	1032.6		
60DBT10I	137.0	1.41	3.4	0.6	1.73	234.8	491.8	34.9	1475.4		
60DBT7I-	137.1	1.72	2.5	0.5	1.60	195.7	392.5	37.9	1570.0		
60DBT7I	165.0	1.16	4	1.1	1.69	235.6	444.7	37.0	1778.8		
60DBT5I-	165.1	1.48	0.9	1.0	1.62	187.7	313.6	42.5	1881.6		
60DBT5I	181.0	1.18	1.2	1.4	1.64	205.8	335.2	42.1	2011.2		
63DU15I-	80.0	5.21	0.5	0.1	1.25	214.7	470.9	38.9	941.8		
63DU15I	87.0	4.38	0.7	0.1	1.31	233.5	495.8	38.2	991.6		
63DU10I-	87.1	5.89	0.4	0.1	1.21	183.2	362.7	42.6	1088.1		
63DU10I	112.0	3.54	0.8	0.2	1.37	235.5	426.5	40.9	1279.5		
63DU7I-	112.1	4.32	0.7	0.2	1.37	203.2	351.9	45.6	1407.6		
63DU7I	130.0	3.23	1.1	0.3	1.46	235.6	389.2	44.7	1556.8		
69DB-10I	84.0	5.19	0.7	0.1	1.37	149.9	368.2	38.9	1104.6		
69DBT10I	132.0	2.13	2.3	0.4	1.61	235.5	485.9	36.0	1457.7		
69DBT7I-	132.1	2.61	1.9	0.3	1.52	197.3	388.5	39.2	1554.0		
69DBT7I	158.0	1.77	2.6	0.7	1.60	235.9	438.1	38.4	1752.4		
69DBT5I-	158.1	2.31	0.5	0.6	1.54	190.2	310.6	44.4	1863.6		
69DBT5I	196.0	1.37	1.1	1.4	1.62	235.8	363.5	43.6	2181.0		
75DU15I-	64.0	13.01	0.1	0.0	1.09	180.1	417.3	42.0	834.6		
75DU15I	83.0	7.47	0.3	0.0	1.29	233.5	488.3	39.7	976.6		
75DU10I-	83.1	10.03	0.2	0.0	1.09	185.5	359.0	44.6	1077.0		
75DU10I	105.0	6.19	0.4	0.1	1.24	234.4	417.3	43.0	1251.9		
75DU7I-	105.1	7.56	0.5	0.1	1.27	204.0	345.6	48.2	1382.4		
75DU7I	121.0	5.71	0.8	0.1	1.37	234.9	380.3	47.4	1521.2		
10DS15E-	16.1	2.03	0.1	0.0	1.54	30.2	200.9	65.4	401.8	200.9	1.9
10DS15E	22.0	1.06	0.3	0.0	1.76	41.3	247.2	55.8	494.4	247.2	2.3

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
13DS15E-	22.1	2.27	0.2	0.0	1.52	54.5	256.8	61.3	513.6	256.8	2.4
13DS15E	31.0	1.03	0.4	0.1	1.73	76.4	326.0	53.7	652.0	326.0	3.1
17DS15E-	31.1	2.21	0.1	0.0	1.53	100.0	342.2	60.7	684.4	342.2	3.2
17DS15E	42.0	1.00	0.5	0.2	1.75	135.1	410.9	55.6	821.8	410.9	3.9
20DS15E-	42.1	1.59	0.2	0.1	1.64	157.9	426.5	60.6	853.0	426.5	4.0
20DS15E	51.0	1.02	0.7	0.2	1.74	191.3	478.1	57.9	956.2	478.1	4.5
32DU15E-	31.0	7.42	0.1	0.0	1.13	75.6	289.4	52.4	578.8	289.4	2.7
32DU15E~	44.0	2.97	0.4	0.1	1.40	107.3	357.2	46.6	714.4	357.2	3.3
32DU15E	56.0	1.68	1	0.1	1.60	132.2	407.4	42.9	814.8	407.4	3.8
32DU10E-	56.1	2.27	0.6	0.1	1.45	99.8	293.5	46.0	880.5	440.3	4.1
32DU10E	82.0	1.02	2.1	0.5	1.65	145.9	366.3	42.4	1098.9	549.5	5.2
32DU7E-	82.1	1.23	1.3	0.4	1.57	122.3	297.1	45.5	1188.4	594.2	5.6
32DU7E	91.0	1.00	1.8	0.6	1.60	135.5	316.3	44.7	1265.2	632.6	5.9
32DU-15E	56.0	1.71	0.7	0.1	1.55	136.6	410.1	43.6	820.2	410.1	3.8
32DUC15E	72.0	1.01	1.9	0.4	1.68	175.6	474.4	41.1	948.8	474.4	4.4
32DU-10E	72.1	1.34	1.1	0.3	1.62	133.9	342.8	44.5	1028.4	514.2	4.8
32DUC10E	83.0	1.01	1.8	0.5	1.67	154.2	373.0	43.3	1119.0	559.5	5.2
33DN-15E	31.0	5.62	0.2	0.0	1.34	74.2	285.3	51.9	570.6	285.3	2.7
33DN~15E	47.0	1.93	0.7	0.1	1.57	112.5	365.7	45.3	731.4	365.7	3.4
33DNX15E	63.0	1.02	1.8	0.3	1.73	150.8	432.7	41.9	865.4	432.7	4.1
33DN-10E	63.1	1.36	1.3	0.2	1.74	114.3	317.9	45.2	953.7	476.9	4.5
33DNX10E	73.0	1.01	2.1	0.4	1.79	132.3	346.0	43.8	1038.0	519.0	4.9
33DNX7E-	73.1	1.23	1.7	0.3	1.66	111.2	274.9	47.0	1099.6	549.8	5.2
33DNX7E	80.0	1.02	2.4	0.5	1.69	121.7	290.2	46.2	1160.8	580.4	5.4
38DU15E-	31.0	10.93	0.1	0.0	1.11	71.7	287.0	51.3	574.0	287.0	2.7
38DU15E~	54.0	2.73	0.6	0.1	1.51	124.9	397.4	42.9	794.8	397.4	3.7
38DU15E	77.0	1.29	1.8	0.3	1.76	178.0	487.6	39.4	975.2	487.6	4.6
38DU10E-	77.1	1.73	1.1	0.3	1.54	133.4	350.7	42.2	1052.1	526.1	4.9
38DU10E	101.0	1.01	2.5	0.7	1.66	174.8	413.4	40.2	1240.2	620.1	5.8
38DU7E-	101.1	1.23	1.7	0.6	1.58	145.6	334.6	43.1	1338.4	669.2	6.3

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
38DU7E	111.0	1.02	2	0.9	1.60	159.8	355.0	42.5	1420.0	710.0	6.7
38DU-15E	64.0	1.97	0.9	0.1	1.51	163.4	447.4	43.2	894.8	447.4	4.2
38DUC15E	89.0	1.01	2.6	0.5	1.70	227.2	545.3	40.4	1090.6	545.3	5.1
38DU-10E	89.1	1.32	1.4	0.4	1.58	175.6	395.0	44.1	1185.0	592.5	5.6
38DUC10E	102.0	1.01	2.3	0.7	1.63	201.1	430.2	43.1	1290.6	645.3	6.0
38DUC7E-	102.1	1.24	1.6	0.7	1.54	158.5	343.8	45.0	1375.2	687.6	6.4
38DUC7E	114.0	1.00	2	1.0	1.56	176.9	369.1	44.3	1476.4	738.2	6.9
41DN-15E	68.0	1.57	1.3	0.2	1.62	176.5	461.4	42.9	922.8	461.4	4.3
41DNX15E	85.0	1.00	2.6	0.5	1.75	220.6	528.0	41.0	1056.0	528.0	5.0
41DN-10E	85.1	1.33	1.9	0.4	1.67	171.4	390.0	45.2	1170.0	585.0	5.5
41DNX10E	98.0	1.01	3	0.7	1.73	197.4	426.1	44.2	1278.3	639.2	6.0
41DNX7E-	98.1	1.22	2.2	0.6	1.68	169.1	341.1	48.3	1364.4	682.2	6.4
41DNX7E	109.0	1.00	3.1	0.9	1.71	187.9	365.4	47.6	1461.6	730.8	6.9
44DU15E-	68.0	2.56	0.9	0.1	1.43	170.5	461.7	42.2	923.4	461.7	4.3
44DU15E	94.0	1.32	2.2	0.4	1.60	235.6	561.5	39.6	1123.0	561.5	5.3
44DU10E-	94.1	1.76	1.1	0.4	1.50	181.2	399.2	43.0	1197.6	598.8	5.6
44DU10E	122.0	1.07	2.3	1.0	1.60	234.9	472.8	41.4	1418.4	709.2	6.6
44DU7E-	122.1	1.29	1.4	0.9	1.54	199.6	392.5	45.4	1570.0	785.0	7.4
44DU7E	139.0	1.01	1.9	1.5	1.56	227.3	428.6	44.7	1714.4	857.2	8.0
48DB-10E	31.0	17.16	0.1	0.0	1.01	50.6	226.7	53.4	680.1	340.1	3.2
48DB~10E	67.0	2.68	1.1	0.1	1.47	109.3	348.9	42.4	1046.7	523.4	4.9
48DBT10E	103.0	1.15	3.4	0.6	1.72	168.0	446.6	38.9	1339.8	669.9	6.3
48DBT7E-	103.1	1.45	2.4	0.5	1.63	139.7	354.5	41.7	1418.0	709.0	6.6
48DBT7E	119.0	1.12	3.6	0.9	1.70	161.2	387.4	40.8	1549.6	774.8	7.3
48DBT5E-	119.1	1.46	1.7	0.8	1.56	126.7	268.0	45.6	1608.0	804.0	7.5
48DBT5E	146.0	1.01	3.4	1.6	1.63	155.4	307.1	44.6	1842.6	921.3	8.6
51DU15E-	84.0	2.29	1.4	0.2	1.44	214.6	526.3	40.8	1052.6	526.3	4.9
51DU15E	92.0	1.90	1.7	0.3	1.48	235.0	556.8	40.1	1113.6	556.8	5.2
51DU10E-	92.1	2.56	1.2	0.2	1.42	181.7	403.4	43.9	1210.2	605.1	5.7
51DU10E	119.0	1.54	2.2	0.6	1.54	234.8	476.0	42.2	1428.0	714.0	6.7

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
51DU7E-	119.1	1.86	1.3	0.6	1.50	200.4	389.6	46.4	1558.4	779.2	7.3
51DU7E	140.0	1.37	1.6	1.1	1.54	235.6	434.9	45.5	1739.6	869.8	8.2
60DB-10E	64.0	5.27	0.5	0.1	1.31	109.7	343.5	44.0	1030.5	515.3	4.8
60DBT10E	130.0	1.30	3.8	0.9	1.69	222.8	522.7	38.6	1568.1	784.1	7.4
60DBT7E-	130.1	1.57	3.3	0.8	1.67	185.7	416.0	41.6	1664.0	832.0	7.8
60DBT7E	146.0	1.30	4.2	1.2	1.66	208.4	448.8	41.0	1795.2	897.6	8.4
60DBT5E-	146.1	1.65	2	1.1	1.59	166.1	313.9	46.5	1883.4	941.7	8.8
60DBT5E	168.0	1.20	3.2	1.8	1.66	191.0	346.4	45.9	2078.4	1039.2	9.7
63DU15E-	68.0	6.03	0.4	0.1	1.19	182.5	469.2	43.8	938.4	469.2	4.4
63DU15E	87.0	3.60	1	0.1	1.35	233.5	544.9	41.7	1089.8	544.9	5.1
63DU10E-	87.1	4.84	0.6	0.1	1.28	183.2	396.6	46.0	1189.8	594.9	5.6
63DU10E	112.0	2.91	1.2	0.3	1.41	235.5	466.4	44.3	1399.2	699.6	6.6
63DU7E-	112.1	3.54	0.9	0.3	1.39	203.2	383.3	49.0	1533.2	766.6	7.2
63DU7E	130.0	2.65	1.7	0.5	1.49	235.6	423.8	48.2	1695.2	847.6	7.9
69DB-10E	72.0	5.88	0.6	0.1	1.32	128.5	370.0	43.7	1110.0	555.0	5.2
69DBT10E	132.0	1.77	3	0.7	1.66	235.5	533.7	39.4	1601.1	800.6	7.5
69DBT7E-	132.1	2.15	2.5	0.6	1.57	197.3	425.5	42.7	1702.0	851.0	8.0
69DBT7E	158.0	1.51	4	1.1	1.64	235.9	479.9	41.8	1919.6	959.8	9.0
69DBT5E-	158.1	1.91	1.5	1.0	1.57	190.2	338.3	47.9	2029.8	1014.9	9.5
69DBT5E	194.0	1.19	2.8	2.1	1.67	233.4	392.7	47.1	2356.2	1178.1	11.0
75DU15E-	64.0	10.67	0.2	0.0	1.06	180.1	457.8	45.5	915.6	457.8	4.3
75DU15E	83.0	6.12	0.5	0.1	1.22	233.5	535.9	43.2	1071.8	535.9	5.0
75DU10E-	83.1	8.22	0.3	0.1	1.13	185.5	391.9	48.1	1175.7	587.9	5.5
75DU10E	105.0	5.09	0.7	0.2	1.30	234.4	455.4	46.4	1366.2	683.1	6.4
75DU7E-	105.1	6.21	0.8	0.1	1.32	204.0	375.8	51.7	1503.2	751.6	7.0
75DU7E	121.0	4.68	1	0.2	1.39	234.9	413.3	50.8	1653.2	826.6	7.7
10DS15S-	15.1	1.90	0.1	0.0	1.64	28.3	178.3	64.1		178.3	1.7
10DS15S	20.0	1.07	0.3	0.1	1.78	37.5	206.8	54.6		206.8	1.9
13DS15S-	20.1	2.29	0.1	0.0	1.52	49.6	215.6	60.0		215.6	2.0
13DS15S	29.0	1.03	0.6	0.1	1.76	71.5	284.5	51.4		284.5	2.7

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
17DS15S-	29.1	2.20	0.2	0.1	1.56	93.6	299.7	58.4		299.7	2.8
17DS15S	39.0	0.99	0.7	0.2	1.77	125.4	359.8	53.1		359.8	3.4
20DS15S-	39.1	1.58	0.4	0.1	1.65	146.6	374.3	58.1		374.3	3.5
20DS15S	47.0	1.01	0.9	0.3	1.75	176.3	418.1	55.4		418.1	3.9
32DU15S-	29.0	7.23	0.1	0.0	1.19	68.5	250.7	49.4		250.7	2.4
32DU15S~	47.0	2.06	0.7	0.1	1.59	111.0	334.9	41.5		334.9	3.1
32DU15S	65.0	1.02	2.2	0.5	1.78	153.5	402.7	37.8		402.7	3.8
32DU10S-	65.1	1.36	1.4	0.4	1.64	115.9	291.1	40.9		436.7	4.1
32DU10S	75.0	1.02	2.4	0.7	1.70	133.5	316.2	39.6		474.3	4.4
32DU7S-	75.1	1.24	2	0.6	1.59	111.8	257.2	42.8		514.4	4.8
32DU7S	83.0	1.01	2.6	0.8	1.61	123.6	273.0	41.9		546.0	5.1
32DU-15S	52.0	1.65	0.9	0.2	1.60	126.8	357.2	40.9		357.2	3.3
32DUC15S	66.0	0.99	2	0.5	1.69	161.0	409.5	38.4		409.5	3.8
32DU-10S	66.1	1.34	1.4	0.4	1.65	122.8	296.9	41.8		445.4	4.2
32DUC10S	76.0	1.00	2.3	0.7	1.70	141.2	322.3	40.6		483.5	4.5
33DN-15S	29.0	5.60	0.2	0.0	1.48	69.4	248.4	49.6		248.4	2.3
33DN~15S	44.0	1.85	0.7	0.1	1.70	105.3	320.0	42.6		320.0	3.0
33DNX15S	58.0	1.01	1.8	0.4	1.83	138.8	374.7	39.3		374.7	3.5
33DN-10S	58.1	1.35	1.5	0.3	1.71	105.3	276.2	42.6		414.3	3.9
33DNX10S	66.0	1.03	2.2	0.5	1.75	119.6	297.2	41.3		445.8	4.2
33DNX7S-	66.1	1.25	1.8	0.4	1.70	100.5	236.7	44.4		473.4	4.4
33DNX7S	73.0	1.02	2.5	0.6	1.72	111.0	250.9	43.5		501.8	4.7
38DU15S-	29.0	10.87	0.1	0.0	1.16	67.1	249.9	49.0		249.9	2.3
38DU15S~	54.0	2.24	0.7	0.2	1.60	124.9	360.7	39.4		360.7	3.4
38DU15S	79.0	1.02	2.7	0.7	1.85	182.7	448.9	35.7		448.9	4.2
38DU10S-	79.1	1.36	2	0.5	1.59	136.9	323.9	38.5		485.9	4.6
38DU10S	92.0	1.01	3.1	1.0	1.63	159.2	354.7	37.4		532.1	5.0
38DU7S-	92.1	1.23	2.3	0.8	1.61	132.6	288.0	40.3		576.0	5.4
38DU7S	101.0	1.02	2.8	1.2	1.62	145.4	305.0	39.6		610.0	5.7
38DU-15S	60.0	1.87	1.2	0.2	1.54	153.1	391.9	40.3		391.9	3.7

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
38DUC15S	81.0	1.01	2.8	0.7	1.68	206.8	467.8	37.6		467.8	4.4
38DU-10S	81.1	1.32	1.9	0.6	1.60	159.9	340.3	41.4		510.5	4.8
38DUC10S	93.0	1.01	3.2	1.0	1.66	183.3	370.4	40.4		555.6	5.2
38DUC7S-	93.1	1.24	2.1	0.8	1.58	144.5	296.5	42.2		593.0	5.6
38DUC7S	103.0	1.02	2.7	1.3	1.60	159.9	316.0	41.5		632.0	5.9
41DN-15S	62.0	1.56	1.4	0.3	1.65	160.9	397.5	40.3		397.5	3.7
41DNX15S	75.0	1.05	2.5	0.6	1.74	194.7	444.9	38.6		444.9	4.2
41DN-10S	75.1	1.42	1.9	0.5	1.66	151.3	330.0	42.8		495.0	4.6
41DNX10S	89.0	1.02	3.4	0.9	1.73	179.3	366.2	41.4		549.3	5.1
41DNX7S-	89.1	1.22	2.6	0.8	1.68	153.6	294.0	45.5		588.0	5.5
41DNX7S	99.0	1.00	3.7	1.2	1.71	170.7	314.5	44.7		629.0	5.9
44DU15S-	64.0	2.40	1	0.2	1.46	160.4	405.0	39.3		405.0	3.8
44DU15S	94.0	1.10	3	0.9	1.65	235.6	509.9	36.1		509.9	4.8
44DU10S-	94.1	1.46	2	0.7	1.55	181.2	364.2	39.6		546.3	5.1
44DU10S	115.0	1.00	3.7	1.5	1.62	221.4	414.7	38.4		622.1	5.8
44DU7S-	115.1	1.20	2.8	1.3	1.56	188.2	345.4	42.3		690.8	6.5
44DU7S	126.0	1.01	3.5	1.9	1.58	206.0	366.9	41.8		733.8	6.9
48DB-10S	29.0	17.05	0.1	0.0	0.99	47.3	198.0	51.1		297.0	2.8
48DB~10S	57.0	3.14	0.9	0.1	1.51	93.0	290.6	40.6		435.9	4.1
48DBT10S	85.0	1.37	2.6	0.6	1.70	138.7	362.6	36.8		543.9	5.1
48DBT7S-	85.1	1.77	2	0.5	1.57	115.3	288.3	39.6		576.6	5.4
48DBT7S	100.0	1.29	3.3	0.8	1.65	135.5	317.0	38.4		634.0	5.9
48DBT5S-	100.1	1.72	1.6	0.7	1.60	106.5	219.3	43.2		657.9	6.2
48DBT5S	124.0	1.15	4.1	1.6	1.69	131.9	251.7	41.9		755.1	7.1
51DU15S-	66.0	3.14	0.9	0.2	1.38	168.6	414.3	39.4		414.3	3.9
51DU15S	92.0	1.59	2.4	0.6	1.55	235.0	505.9	36.7		505.9	4.7
51DU10S-	92.1	2.12	1.6	0.5	1.47	181.7	368.3	40.5		552.5	5.2
51DU10S	119.0	1.29	3.4	1.2	1.59	234.8	434.5	38.9		651.8	6.1
51DU7S-	119.1	1.55	2.4	1.1	1.53	200.4	356.9	42.9		713.8	6.7
51DU7S	140.0	1.14	3.8	2.0	1.57	235.6	398.5	42.1		797.0	7.5

Tabulation of girder analysis (24 page table) Part III

ID	Span (feet)	Span/ 800 LL defl	Camber (inch)	Comp defl (inch)	StressMu/ StressCrack	Weight (k)	ult reaction (k)	Merit ($/SF)	Pier col (K)	Abut col (K)	Abut Spread (feet)
60DB-10S	68.0	3.83	0.9	0.1	1.43	116.5	323.4	39.9		485.1	4.5
60DBT10S	106.0	1.57	3.1	0.8	1.67	181.6	418.3	36.4		627.5	5.9
60DBT7S-	106.1	1.94	2.7	0.7	1.59	151.5	333.4	39.3		666.8	6.3
60DBT7S	124.0	1.45	4.2	1.2	1.68	177.0	367.7	38.4		735.4	6.9
60DBT5S-	124.1	1.88	2.4	1.0	1.60	141.2	257.5	43.8		772.5	7.2
60DBT5S	148.0	1.35	4.2	2.0	1.68	168.4	290.4	42.9		871.2	8.2
63DU15S-	70.0	4.68	0.6	0.1	1.28	187.9	434.5	40.0		434.5	4.1
63DU15S	87.0	2.99	1.3	0.3	1.41	233.5	495.8	38.2		495.8	4.6
63DU10S-	87.1	3.99	0.9	0.2	1.33	183.2	362.7	42.6		544.1	5.1
63DU10S	112.0	2.41	2	0.6	1.47	235.5	426.5	40.9		639.8	6.0
63DU7S-	112.1	2.19	1.4	0.5	1.43	203.2	351.9	45.6		703.8	6.6
63DU7S	130.0	1.64	1.9	0.9	1.49	235.6	389.2	44.7		778.4	7.3
69DB-10S	72.0	4.86	0.8	0.1	1.37	128.5	337.1	40.3		505.7	4.7
69DBT10S	123.0	1.69	3.8	0.9	1.67	219.5	464.3	36.4		696.5	6.5
69DBT7S-	123.1	2.06	3.1	0.8	1.61	183.8	371.1	39.6		742.2	7.0
69DBT7S	142.0	1.59	4.5	1.4	1.68	212.0	407.5	38.9		815.0	7.6
69DBT5S-	142.1	2.05	2.5	1.2	1.58	171.0	288.1	44.9		864.3	8.1
69DBT5S	170.0	1.34	4.2	2.4	1.65	204.5	327.3	44.1		981.9	9.2
75DU15S-	74.0	6.43	0.5	0.1	1.22	208.2	455.2	40.6		455.2	4.3
75DU15S	83.0	5.07	0.8	0.1	1.30	233.5	488.3	39.7		488.3	4.6
75DU10S-	83.1	6.78	0.5	0.1	1.21	185.5	359.0	44.6		538.5	5.0
75DU10S	105.0	4.20	1	0.3	1.34	234.4	417.3	43.0		626.0	5.9
75DU7S-	105.1	5.11	0.9	0.3	1.34	204.0	345.6	48.2		691.2	6.5
75DU7S	121.0	3.86	1.4	0.5	1.42	234.9	380.3	47.4		760.6	7.1