APPENDIX G

OWNER/AGENCY POLICIES AND PROCEDURES

Task 2 of NCHRP Project 12-79 involved the synthesis of pertinent owner/agency policies and practices. To this end:

1. The Project Team coordinated with AASHTO/NSBA Steel Bridge Collaboration Task Group 13 (TG13), which completed a Survey of Current Practice in Steel Girder Design in Summer 2008.

2. The Project Team conducted its own survey of current policies and procedures in Summer 2008.

3. The Project Team reviewed a number of guideline documents, including (but not limited to):

   - The AASHTO/NSBA document G12.1 – 2003, *Guidelines for Constructability*,

   - The AASHTO/NSBA document S10.1 – 2007, *Steel Bridge Erection Guide Specification*,

   - NCHRP Synthesis 345 – *Steel Bridge Erection Practices*, and

   - Vol. 1, Ch. 14 of the *Highway Structures Design Handbook, Steel Erection for Highway, Railroad and other Bridge Structures*.

G.1 AASHTO/NSBA STEEL BRIDGE COLLABORATION TASK GROUP 13 SURVEY

The AASHTO/NSBA Steel Bridge Collaboration formed Task Group 13 in May 2007, with the mission of developing guidelines for the analysis of steel bridges. One of the Task Group's first objectives was to survey the current practices of steel girder design throughout the US. The Task Group wanted to see how the various owner-agencies and other organizations are designing various types of steel girder bridges with the following goals in mind:

- Assessing the current state of practice in steel girder design,
- Noting trends in steel girder design,
- Collecting guidelines, methods, and tools,
- Collating a set of "best practices" guidelines and suggestions for publication in an AASHTO/NSBA Steel Bridge Collaboration steel girder design document.

The survey addressed a wide variety of steel girder bridge types. If there was a particular type of steel girder bridge that a given organization did not typically design, they were encouraged to feel free to skip that section of the survey, or to offer opinions as to how they would approach that type of design if they were to perform it.

In order to establish a consistent context for communication of policies and practices, the survey included definitions of various analysis methods, which are listed below:

- *Hand Analysis Methods:* Any analysis/design method that can be performed completely by hand (even if it is sometimes or often programmed into a spreadsheet or computer program). Examples include the Moment Distribution Method, the V-Load Method, the M/R Method, etc.
- *Line Girder Analysis Methods:* Any analysis/design method that isolates a single tangent girder from the rest of the superstructure system and evaluates that girder individually, with the rest of the superstructure system considered only by means of boundary conditions, live load distribution factors, etc.
- *Grid Analysis Methods:* The characterization as a Grid analysis in this survey was indicated to mostly address 2D Grid or Grillage analysis methods. This includes any analysis/design method that includes a computerized structural analysis model where the superstructure is typically modeled as a two-dimensional array of nodes and line elements, and where the girders and cross frames or diaphragms are typically modeled using line elements, where the analysis displacements are solely vertical displacements and rotations about axes in a horizontal plane, and where the loads considered are primarily out of plane vertical (gravity) loads. Two variants are listed below ("Plate and Eccentric Beam Grid" and "3D Grid"). The survey participants were asked that if they use one of these variants (or another variant) to please indicate so in their survey responses.
- *"Plate and Eccentric Beam Grid" Analysis Methods:* A variant on 2D Grid/Grillage analysis model, where the deck is modeled using plate or shell elements, while the girders and cross frames are still modeled using line elements, offset from the deck elements. The survey participants were asked that if they perform Grid analyses using methods that address some of these refinements, to please indicate so in their survey responses.
- *"3D Grid" Analysis Methods:* This is a modification of a 2D Grid analysis, where more degrees of freedom are modeled. Some typical additions that separate 3D Grid methods from 2D Grid methods include modeling of warping stiffness and warping response of I-shaped girders, modeling of the shear stiffness of cross frames or diaphragms, and modeling of girder supports, lateral bracing, and/or cross-frames or diaphragms at their physical elevation within the structure. The survey participants were asked that if they perform Grid analyses using methods that address some of these refinements, to please indicate so in your survey responses.
- *3D Analysis Methods:* Any analysis/design method that includes a computerized structural analysis model where the superstructure is modeled fully in three dimensions, including: modeling of girder flanges using line/beam elements or plate/shell/solid type elements; modeling of girder webs using plate/shell/solid type elements; modeling of cross frames or diaphragms using line/beam, truss, or plate/shell/solid type elements (as appropriate) and modeling of the deck using plate/shell/solid elements.

A total of 37 state DOTs responded to the survey. These surveys were grouped and collectively titled the "AASHTO responses." Most AASHTO surveys were filled out in a relatively complete manner in terms of answering the "check box" questions, but expanded commentary by the survey respondents was sporadic.

A total of six responses were received from railroad bridge engineers, representing either railroad owner-agencies or consulting engineers who specialize in railroad bridge engineering. These surveys were grouped and collectively titled "AREMA responses." In general, the AREMA surveys were not completely filled out – the respondents typically limited their comments to the tangent (straight) plate girder / rolled beam questions.

A total of seven responses were received from others during the initial phase of the survey (Task Group 13 is currently soliciting more responses to the survey from designers outside of DOT organizations). Four of these were from consulting engineers, two from owner-agencies other than US state DOTs, and one from a fabricator/erector. These surveys were grouped and collectively titled "At Large responses." Most At Large surveys were filled out in a relatively complete manner in terms of answering the "check box" questions, but expanded commentary by the survey respondents was sporadic.

G.2 NCHRP 12-79 PROJECT TEAM SURVEY

The NCHRP 12-79 Project Team also conducted a focused survey of owner/agency practices and procedures. The Project Team recognized the work already accomplished by TG13 and chose to conduct a focused survey directed primarily at the state DOTs (see Appendix F). All 50 states as well as the commonwealth of Puerto Rico were contacted. The Project Team sent a brief introductory letter, accompanied by a brief description of the NCHRP 12-79 Project and the Project Team, along with a request for existing bridge plans and for any policies, procedures, or comments associated with analysis methods and construction engineering for steel deck girder bridges.

Thirty-one of the 51 contacted owner/agencies responded in some way to this request for information and input. The responses included a large number of existing bridge as well as a number of policy, procedure, and/or guideline documents.

G.3 DISCUSSION OF POLICIES, PROCEDURES AND PRACTICES OF VARIOUS OWNER/ AGENCIES

G.3.1 Overall Trends and Comments

As might be expected, there were wide variations in the responses to various survey questions from the state DOTs. Each state is somewhat unique in terms of how much of their bridge design and construction volume consists of steel girder bridges, as well as being unique in the specific nature of their steel girder bridges. Some states do no steel girder design or construction at all, while other states use steel girders extensively in a wide range of simple and complex bridge applications. Some states use steel girders primarily in simple applications (e.g., tangent, non-skewed rolled beams and plate girders), while other states use steel girders primarily in complex applications (e.g., longer spans, curved girder bridges, etc.) where prestressed concrete girders or other types of bridges are not feasible. As a result, there is understandably some fairly wide scatter in the responses to many of the questions in the survey.

However, many general trends were also apparent. There appears to be a growing interest in some of the more subtle nuances of steel girder behavior and analysis as designers face more challenging steel bridge projects featuring longer spans and more severe curvature and skew. But at the same time, there is still a great reliance in, and confidence in, simple, tried and true analysis methods.

The following general points can be drawn from the surveys:

- Some states are realizing a need for more careful analysis for some of the more complex steel girder bridges they are increasing faced with.

- Some states feel content with their current tools and methods. This is often linked to trends in those states which are not leading them to face more complex steel bridge design and construction projects.

- Among all states, even among the subset of states that are facing more complex steel girder bridges and are considering the need for more rigorous analysis methods, there is a wide variety of practices being used for steel girder bridge design.

More detailed summaries of the answers to the various survey questions are presented below, grouped to match the titled sections of the survey.

G.3.2 Responses to General Questions

In terms of identified needs for better guidance in the area of analysis of steel girder bridges:

- There were numerous references to a desire for a better understanding of the behavior and analysis of skewed bridges.

- There were several references to a desire for a better understanding of the behavior and analysis of curved girder bridges.

- There were several references to a desire for a better understanding of constructability of steel girders, stability of steel girders during construction, and behavior of steel girders through all stages/phases of construction.

In terms of types or classes of steel girder bridges where there have been more than occasional problems during construction, where the problems can be traced back to issues with the original analysis and design:

- There were several references to issues with staged (or phased) construction.

- There were several references to issues with dead load deflections.

- There were several references to issues with skewed bridges.

One state responded with a very interesting story of a curved bridge which exhibited a deflected shape upon erection that was significantly different from the deflected shape predicted by the originally used grid analysis. The structure subsequently needed to be reanalyzed during construction using a non-linear 3D analysis to address second order effects. The state believes this to be an example of where a grid analysis approach "was not sufficient to capture the behavior of the structure and are looking to establish some possible guidelines for curved structures regarding the level of analysis that needs to be performed depending upon geometry and complexity."

*G.3.2.1 Responses to Questions About Tangent (Straight) Steel Plate Girders or Rolled Beams with No Skew or Limited Skew (**S**kewed less than 20^o from Nonskewed)*

Tangent (straight) steel plate girders or rolled beams with no skew or limited skew were listed as being commonly used by approximately 60% of the responding states. They are used in both integral end bent and conventional end bent applications. They are typically used in both simple span and continuous applications, on both narrow and wide bridges. They are used in a wide range of span lengths, with medium span lengths (100' to 250') being most prevalent.

Some form of line girder analysis, often by hand calculations, but more often by in house or commercial software, is by far the most prevalent design method being used. A wide range of software packages (ten or more different commercial packages, and probably an equal or greater number of in-house software packages) are being used.

A similarly wide range of reference documents are used as guidelines for these designs.

A wide variety of comments were received regarding widening and/or staged construction, including a few problems, but there did not appear to be a significant link from any problems directly to the analysis methods used.

G.3.2.2 Responses to Questions About Tangent (Straight) Steel Plate Girders or Rolled Beams, Significantly Skewed (Skewed More than 20^o from Nonskewed)

As might be expected, tangent (straight) steel plate girders or rolled beams, significantly skewed, were listed less often as being routinely used, but still nearly half of the responding states listed them as being routinely used.

The use of integral end bents with skewed tangent girder bridges with is less frequent than with non-skewed tangent girder bridges, and even the states that routinely use integral end bents with skewed tangent girder bridges typically limit the permissible skew.

These types of bridges are typically used in both simple span and continuous applications, on both narrow and wide bridges. They are used in a wide range of span lengths, with medium span lengths (100' to 250') being most prevalent.

Again, as for non-skewed tangent girder bridges, some form of line girder analysis, often by hand calculations, but more often by in house or commercial software, is by far the most prevalent design method being used. Again, as for non-skewed bridges, a wide range of software packages is being used.

However, for these skewed tangent girder bridges, the use of either a grid analysis or a 3D analysis is more prevalent, being mentioned 8 times for non-skewed bridges, but 16 times for skewed bridges.

Special considerations and limitations mentioned for skewed bridges were more specific than for non-skewed bridges, with several responses mentioning special consideration being given to cross frame analysis, design, and detailing.

Most of the issues associated with widening and/or staged construction for skewed tangent girder bridges seem to be similar to those listed for non-skewed tangent girder bridges.

G.3.2.3 Responses to Questions About Curved Steel Plate Girders or Rolled Beams with No Skew or Limited Skew (Skewed less than 20^o from Nonskewed)

Curved steel plate girder or rolled beam bridges with no skew or limited skew were reported as being less frequently used than tangent (straight) girder bridges, but still more than half of the responding states reported using them either routinely or occasionally, with some mention that steel girders are often selected for curved bridges, if there is no way to avoid curvature on the bridge.

The use of integral end bents with curved steel girder bridges appears to be much less common than for tangent (straight) girder bridges.

Curved steel girder bridges appeared to be more commonly used in continuous rather than simple span applications, although simple span applications were certainly not rare. Curved steel girder bridges also appeared to be more commonly used in narrow bridge applications rather than wider bridge applications. They are used in a wide range of span lengths, once again with medium span lengths (100' to 250') being most prevalent.

In terms of analysis methods used, the VLOAD method, either by hand or via a computer program, was listed as being used or recommended by 18 of the responding states, although two of those respondents mentioned DESCUS or MDX as their VLOAD software package, which seemed odd since DESCUS and MDX are better known as grid analysis programs. Meanwhile 23 of the responding states said that they used or recommended grid analysis for curved, non-skewed bridges, and 7 of the responding states said that they used or recommended 3D analysis. (Recall that for this question, the respondents were directed to indicate all methods that apply, hence the number of responses sums to more than the 37 responding states). So, in summary, the VLOAD method appeared to still be popular and commonly used, although grid analysis methods appeared to be most prevalent for these types of structures, with 3D analysis methods being the least prevalent.

In terms of limitations, none of the responding states specifically indicated limits on span length or degree of curvature for any given analysis approach (VLOAD, grid, or 3D), although one state hinted that limits on when to move from grid to 3D were being evaluated.

There was much less comment on widening and/or staged construction of curved, non-skewed bridges than was provided for tangent (straight) girder bridges. Of perhaps the most significance were a few comments indicating that curved steel bridges were seldom, if ever, widened, at least in some states.

G.3.2.4 Responses to Questions About Curved Steel Plate Girders or Rolled Beams, Significantly Skewed (Skewed more than 20^o from Nonskewed)

The trend for less application with more complexity continued as curved steel girder bridges with significant skew were listed as less frequently used than curved non-skewed steel girder bridges.

The use of integral end bents for curved steel girder bridges with significant skew was even less than for curved, nonskewed steel girder bridges.

Curved steel girder bridges with significant skew appeared to be more commonly used in continuous rather than simple span applications, although simple span applications were certainly not rare. Curved steel girder bridges with significant skew also appeared to be more commonly used in narrow bridge applications rather than wider bridge applications. They are used in a wide range of span lengths, once again with medium span lengths (100’ to 250’) being most prevalent.

Versus curved, non-skewed steel girder bridges, curved steel girder bridges with significant skew were less likely to be analyzed by the VLOAD method, although the VLOAD method was still listed as used or recommended by 13 of the responding states. Meanwhile, the use of grid or 3D analysis methods was more likely for curved steel girder bridges with significant skew, with grid analysis methods being used or recommended by 20 of the responding states, and 3D analysis methods being used or recommended by 10 of the responding states. (Recall that for this question, the respondents were directed to indicate all methods that apply, hence the number of responses sums to more than the 37 responding states). So, in summary, the VLOAD method appeared to still be popular and commonly used, but less so than for curved, non-skewed bridges, with grid analysis methods appearing to still be most prevalent for these types of structures, but with 3D analysis methods being more popular for curved, significantly skewed bridges than for curved, non-skewed bridges.

Few comments were received regarding limitations or special considerations, or for wider bridges and/or staged construction.

G.3.2.5 Responses to Questions About Tub Girders or Box Girders

Much less response was received regarding tub or box girders than was received regarding rolled beams and plate girders. In general, it appeared that tub or box girders are much less common among the states.

In terms of analysis methods, the trends for steel tub or box girders seemed to match the trends for rolled beams and plate girders, with line girder analysis methods being more prevalent than grid or 3D analysis methods for tangent (straight) girder bridges, and grid analysis methods, and to a lesser extent 3D analysis methods, being more prevalent for curved girder bridges. There was however, a noticeable shift toward more refined methods being preferred for tub or box girders vs. rolled beams or plate girders, i.e., for tangent tub or box girders there was a greater percentage of votes for grid analysis than was seen for tangent rolled beams or plate girders, and likewise for curved tub or box girders there was a greater percentage of votes for 3D analysis than was seen for curved rolled beams or plate girders.

G.3.2.6 Responses to Questions About Bridges with Significantly Complex Framing Plans (Variable Girder Spacing, Bifurcation of Girders, Elevated Tee-Intersections, Single Point Urban Interchanges, etc.)

There was little response to these questions and few if any trends were observed. Single Point Urban Interchanges (SPUIs) were mentioned as becoming more prevalent. Line girder, grid, and 3D analysis methods were all listed as being recommended by nearly equal numbers, but not much could be drawn from that voting given the wide range of structures covered by this question and the lack of much in the way of expanded responses from the survey respondents.

G.3.3 Specific Examples of Individual State DOT Policies and Practices

The examples listed below represent only a sampling of individual state DOT policies and practices and are not meant to be an exhaustive listing either with regard to the number of states mentioned nor with regard to the breadth of each state’s guidelines. Any notable omissions of specific states or their specific guidelines is unintentional. At this stage in the project, the various policies and procedures are being synthesized by the Project Team without making any value judgments.

A number of state DOTs have developed stand-alone documents related to steel bridge design, detailing, fabrication, and/or erection, including:

- Caltrans has the *Preferred Practices for Steel Plate Girder Bridge Design, Fabrication, and Erection*, 2002
- TxDOT has the *Texas Steel Quality Council Preferred Practices for Steel Bridge Design, Fabrication, and Erection*, 2005
- There are also the *Mid-Atlantic States Structural Committee for Economical Fabrication (SCEF) Standards*

The Caltrans document was developed by Caltrans, whereas the Texas and Mid-Atlantic States documents were developed by volunteer committees comprised of various owner and industry representatives. These documents are generally very thorough and comprehensive, but are focused on design, detailing, and fabrication issues and offer only limited guidance on analysis issues.

Florida DOT (FDOT) has some explicit guidelines on analysis methods summarized in Table G.1

Table G.1 Explicit Florida DOT guidelines.

Analysis Type	Bridge Type
1D	Straight bridges w/ skews < 10 degrees
2D (grid)	Straight bridges w/ skews > 10 degrees Curved bridges w/ radius >700’
3D	Curved bridges w/ radius <700’

FDOT also has some explicit requirements related to scope and responsible party for constructability checks and erection plans.

Pennsylvania DOT (PennDOT) provides analogous guidelines for curved bridges in their design manual (DM4), where they require that curved girder bridges be analyzed using a “refined method of analysis” which they later define as either a 3D finite element method or a 2D grillage analogy.

Idaho DOT (ITD) has a specific policy and guidelines on prediction of twist in tangent girder bridges with skewed supports, based on simple geometric relationships. ITD also recommends assuming uniform dead load deflection among all girders (interior and exterior) during slab placement. ITD also recommends consideration of fascia girder twist deformations due to overhang loads, referencing AASHTO LRFD and KDOT guidelines.

Illinois DOT (IDOT) has a standard special provision requiring submittal of a detailed Erection Plan prepared by an Illinois PG. They also require submittal of erection engineering calculations. In addition, the original designer is required to fully investigate at least one erection sequence. IDOT's bridge design manual offers some guidance on how to deal with skewed and curved structures: for severely skewed bridges (>45º), they allow use of an assumed 10 ksi lateral flange bending stress. They also provide guidance on how to consider composite action (typically not considered in negative moment regions on straight or mildly curved girders, considered in more severely curved bridges, with the definition of "curved" being consistent with AASHTO GHC-4). IDOT requires the use of standard holes in the plans for curved girder bridges, but also requires that the connection be designed as if oversize holes were being use (to allow for "a measure of redundancy"). They require detailing for the webs to be plumb at the steel dead load condition.

North Carolina DOT (NCDOT) has a comprehensive Structure Design Manual that addresses steel girder bridge design with some specific design guidelines and some specific detailing suggestions. But more significant are their recent guidelines related to adjustments to dead load deflections in tangent steel girder bridges. NCDOT sponsored extensive research at North Carolina State University to perform field measurements and analytical studies to develop a method for adjusting line girder analysis results to account for girder spacing, skew, interior vs. exterior girder effects, etc. The resulting guidelines are presented in the form of simple equations, but an accompanying spreadsheet which automates the calculations is also offered. The goal of this research and NCDOT's position in general is to try to find ways to use simpler analysis methods whenever possible, while recognizing some of the limitations of these simpler methods and providing procedures for adjusting the results of simpler analyses to better approximate actual behavior in more complex structures.

Ohio DOT (ODOT) recently adopted new policies related specifically to skewed bridges. These include:

- For bridges with skew angles less than 30 degrees, the effects of skew do not have to be considered.

- For bridges with skew angles between 30 and 45 degrees, the differential deflection between beams must be less than the beam spacing divided by 100. If not, a refined analysis must be performed and the beams may have to be redesigned or other measures may have to be taken.

- For bridges with skew angles greater than 45 degrees, a refined analysis must be performed. If the girder twist is greater than 1/8 inch per foot, the beams either have to be redesigned or other measures may have to be taken.

- The effects of twisting of the overhang bracket are to be investigated.