FRA–670/ International Gateway–8.87 (Parts 1 & 2)

Port Columbus International Airport
Columbus, Ohio

OWNER
ODOT, District 6
400 East William Street
Delaware, Ohio 43015

PROJECT COST
$40 Million (Est. Construction)

SCHEDULE
Part 1
2006 (Plan Completion)
2007-08 (Construction)
Part 2
2008 (Plan Completion)
2008-09 (Construction)

KEY ELEMENTS

- *Alternatives Analysis*
- *Interchange Modification Study Update*
- *Environmental Document Addendum/Update*
- *Grade Separation*
- *Roundabout Evaluation and Design*
- *Maintenance-of-Traffic*
- *Signal Design*
- *Value Engineering*
- *MSE Walls*
- *Highly Skewed Ramp Bridges*

The FRA-670 / International Gateway project involves the design of a grade separation between I-670/International Gateway and Stelzer Road and realignment of International Gateway for the proposed relocation and expansion of the airport terminal facilities at the Port Columbus International Airport in Columbus, Ohio.

The intersection of I-670/International Gateway and Stelzer Road will be reconstructed to modify the current at-grade intersection. When completed, I-670/International Gateway through traffic will go over Stelzer Road on two new bridges. Local traffic on I-670/International Gateway will continue to use the modified at-grade intersection with Stelzer Road. To the east of Stelzer Road, International Gateway will be realigned and lowered to pass under two new cross-over taxiway bridges being built to connect the main north and south runways, a new perimeter road bridge adjacent to the cross-over taxiway bridges and a new access road bridge adjacent to the perimeter road bridge for access to the existing parking lot.

The project included evaluation of alternatives to the previously approved Single-Point-Urban-Interchange (SPUI) including an evaluation of the approved Categorical Exclusion document and preparation of an addendum to the document. The approved Interchange Modification Study was also being reevaluated for the new interchange configuration. Access to the terminal and the parking lots will be revised. A roundabout is proposed for access to the Red Lot parking from both International Gateway and Stelzer Road. Access to the parking lot from the terminal and access to westbound traffic will be provided by a new bridge over International Gateway.

The project has been designed in two Parts. Part 1 includes construction of the relocated roadway east of Stelzer Road and new at-grade intersections with Stelzer Road. Temporary connections will be made to I-670/International Gateway west of Stelzer Road. Part 2 will include the separation of I-670/ International Gateway traffic from Stelzer Road and reconstruction of the roadway and bridges west of Stelzer Road.

DLZ is responsible for the overall design of this project and for coordination with a separate contract that includes two new crossover taxiways between the main north and south runways. The design elements include roadway, drainage, traffic control, signals, bridges, maintenance-of-traffic plans, interchange lighting, survey, geotechnical engineering, right-of-way plans, and SWPPP.

The complexities of the 3-highly skewed ramp bridges are one of the highlights of the project and are the focus of this article. The bridge skews include skew angles of 63° and two at 69°. Most roadway alignments are designed to avoid such high skews on bridges because of the known complexities associated the highly skewed bridges. However, due to various geometric constraints related to the location of the roadway ramps, the high skews on the bridges were generally unavoidable.

Design Criteria for Highly Skewed Bridges

The 3-highly skewed ramp bridges consist of:

- Bridge No. FRA-670-0898B (Ramp E1 over Ramp D1) (63° skew)
- Bridge No. FRA-670-0924B (Ramp F1 over Ramp G1) (69° skew)
- Bridge No. FRA-CR023-0522B (Red Lot Ramp over Int'l Gateway) (69° skew)

DLZ designed each bridge in accordance the American Association of State Highway and Transportation Officials (AASHTO) Standard Specification for Highway Bridges, 17th Edition as well as the Ohio

Department of Transportation's (ODOT) Bridge Design Manual. In cooperation with ODOT, DLZ evaluated the bridge superstructures utilizing a finite element model, thereby defining each steel plate girder member including stiffeners, each cross frame member, and the composite reinforced concrete deck. The main concern with the construction of highly skewed bridges is in the overall stability of the superstructure framing during the pouring of the bridge deck. The ODOT Office of Structural Engineering provided additional criteria applicable to the design of bridges with high skews. During the deck pour, the girder twist shall be no more than 0.6°, equivalent to 1/8" per foot of girder height, and the differential deflection between adjacent girders shall be no more than 1.0".

The design loading includes HS25, Case II, and the Alternate Military Loading plus a future wearing surface of 60 pounds per square foot.

The design deck slab thickness is 8.50", which includes a 1.0" monolithic wearing surface. The deck slab loads used to design the superstructure include an additional concrete thickness of 1.0" on Ramp F1 and Red Lot Ramp and 0.5" on Ramp E1. This additional concrete is provided so that the bridge deck surface can be diamond ground to final elevation. The grinding is necessary because the finishing machine will be propelled across the bridge at a 50° skew left forward skew in accordance with the ODOT Construction and Material Specifications (CMS). With the finishing machine set on a skew, the combination of horizontal alignment, vertical curvature and superelevation on each bridge will make it difficult for commonly available finishing machines to place the concrete to the correct final grade.

Each bridge carries a 16'-0" wide single-lane one-way ramp with a 6'-0" left shoulder and an 8'-0" right shoulder, for a toe-to-toe of parapet width of 30'-0". The out-to-out of deck width for each bridge is 33'-0". Structure data specific to each bridge is as follows:

FRA-670-0898B (Ramp E1)

- Span measured along reference chord: 120'-2"
- Span measured along girder lines: 118'-2 3/4"
- Skew with respect to reference chord: 63°17'45" left forward
- Alignment: 6°30'00" curve left
- Superelevation: 0.057 ft/ft, constant
- Framing: 5 tangent & parallel girders, 4 spaces at 6'-10" c/c, with a flared girder spanning 58'-8 1/4" at the left forward end

FRA-670-0924B (Ramp F1)

- Span measured along reference line and girder lines: 149'-4"
- Skew with respect to reference line and girder lines: 68°46'06" left forward
- Alignment: 9°00'00" curve right, tangent, 4°15'00" curve left
- Superelevation: varies, transitions through level section on bridge
- Framing: 5 tangent & parallel girders, 4 spaces at 7'-3" c/c

FRA-CR023-0522B (Red Lot Ramp)

- Span measured along reference line and girder lines: 134'-6 1/8"
- Skew with respect to reference line and girder lines: 68°46'06" left forward
- Alignment: 8°00'00" curve right, tangent, 8°45'00" curve left
- Superelevation: varies, transitions through level section on bridge
- Framing: 5 tangent & parallel girders, 4 spaces at 7'-3" c/c, with a flared girder spanning 36'-3" at the left forward end

Details of the Refined Analysis

DLZ performed a line girder analysis to determine girder sizes with which to begin the refined analysis and as a final check to ensure the girders satisfied standard AASHTO Load Factor Design criteria.

DLZ used LUSAS Bridge, Version 14.1-3 to perform the refined analysis. LUSAS Bridge is a three-dimensional finite element analysis package that consists of a "Modeler" and a "Solver". The LUSAS "Modeler" is a Windows-based interface through which the input is created and the output is viewed. The LUSAS "Solver" is a DOS-based utility that performs the computations. General information about LUSAS can be found online at: http://www.lusas.com

For each bridge, DLZ created an initial LUSAS finite element model using the member sizes from the preliminary line girder analysis. Deck slab loadings were calculated in a spreadsheet and applied to the model, the analysis was run, and girder twist and differential deflections were evaluated. For all three structures, DLZ found that girder twist and differential deflections exceeded the criteria prescribed by ODOT. To meet the criteria, ***DLZ determined that it was necessary to increase the stiffness of the girder section over what was required by line girder analysis and utilize an internal lean-on bracing system for the deck pour.***

With a lean-on bracing system, some of the crossframe members are not installed until after the deck pour. This made it necessary to create different models to analyze the load cases occurring at the various stages of bridge construction. For each bridge, the following non-composite load cases were evaluated using a finite element model that included only the structural steel:

Dead Load:

- Self-weight of main girders.
- Self-weight of crossframe members installed prior to the deck pour.
- Self-weight of flared girder installed after main girder erection (if present).
- Self-weight of the deck slab wet concrete.

Live Load:

- Finishing machine running across the bridge.

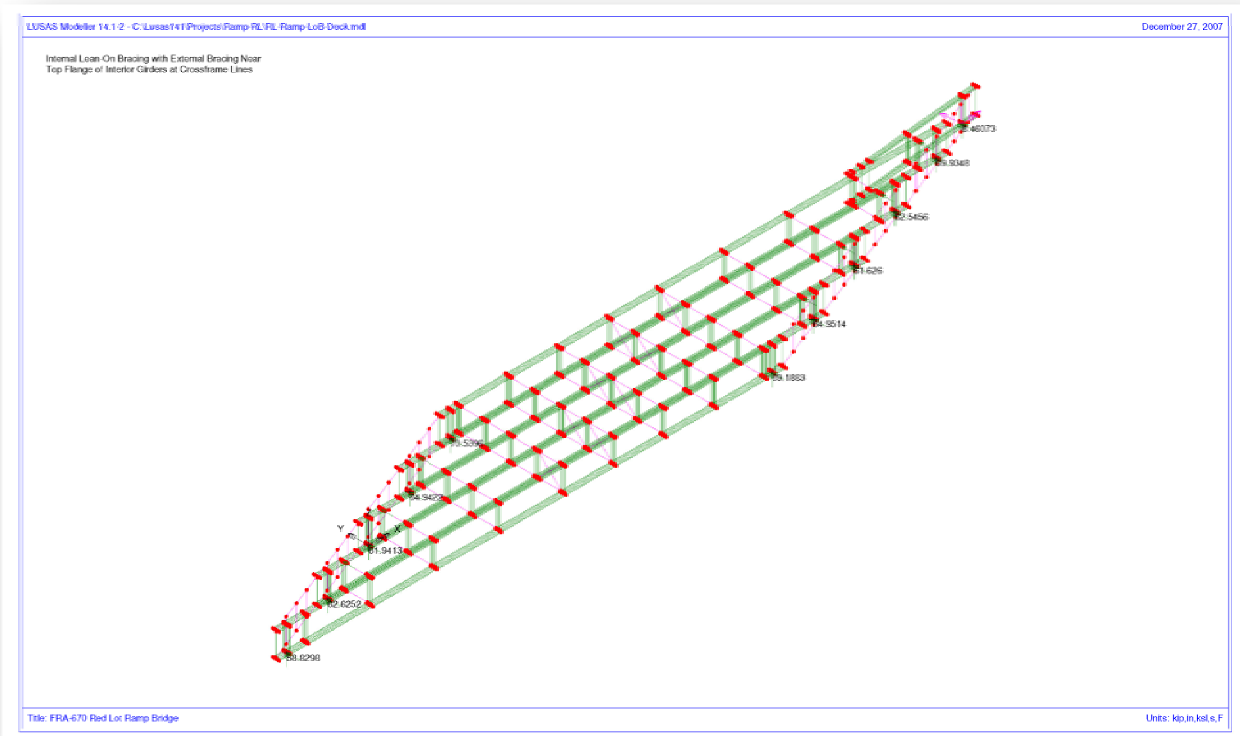
For each bridge, DLZ evaluated the following composite load cases using a finite element model that included the reinforced concrete deck made composite with the structural steel girders:

Dead Load:

- Self-weight of parapets and crossframe members installed after the deck pour.
- Future wearing surface.

Live Load:

- HS25 Truck Load, including impact
- HS25 Lane Load, including impact



3-Dimensional Model of Steel Framing showing Lean-on Bracing System

Lean-on Bracing System

For each bridge, the lean-on bracing system consists of installing intermediate crossframe diagonals only in selected bays in the center portion of the span and providing temporary braces at crossframe bays near the ends of the span. Omitting the intermediate crossframe diagonals from the bays where differential deflections are the largest serves to reduce girder twisting by allowing the girders to deflect independently under loading from the deck pour.

The following references provided guidance in the design of the lean-on bracing system:

- Herman, Helwig, Holt, Medlock, Romage, and Zhou, "Lean-on Crossframe Bracing for Steel Girders with Skewed Supports"

- Beckmann and Medlock, "Skewed Bridges and Girder Movements Due to Rotations and Differential Deflections"
- Yura, J. A. (2001), "Fundamentals of Beam Bracing", Engineering Journal, American Institute of Steel Construction, 1st Quarter, pp. 11-26

The following summarizes the procedure that DLZ followed to design the lean-on bracing system and intermediate crossframes:

- Calculated girder moments due to girder self-weight using line girder methods.
- Performed finite element analysis with LUSAS to determine girder moments that occur during the deck pour and temporary brace forces.
- Calculated required stiffness and provided stiffness for each line of bracing during the deck pour to verify that adequate bracing is provided.
- Calculated bracing forces occurring during the deck pour and summed with non-composite bracing forces obtained from the finite element analysis to verify that crossframe member capacity is adequate in the lean-on bracing condition.
- Calculated bracing forces occurring under composite dead and live loads and summed with non-composite bracing forces to verify that crossframe member capacity is adequate in the final condition.
- Calculated temporary brace forces to verify that member capacity is adequate.

It should be noted that as a result of the refined analysis of the superstructure steel, the reactions and rotations determined for the various stages of construction were accounted for in the bearing designs. Circular laminated elastomeric bearings were found to be the most cost effective bearing type.

Summary

When construction is complete in 2009, the FRA-670 / International Gateway project will greatly improve traffic flow in and out of the airport terminal facilities at the Port Columbus International Airport. Many users will have little hint of the complexities involved with the structures they cross as they travel from point A to point B. The highly skewed bridges of the FRA-670 / International Gateway project should prove to be a long-term, minimal maintenance link in the roadways to and from the Port Columbus International Airport. Use of this specialized software and the unique analysis described above provides the travelling public with a high degree of safety on the new roadway system.

For more information on this project, please contact Matt Lawler via email at mlawler@DLZ.com