A Structural Facelift

Blast Resistant Over-Clad of 33-Story 1967 Federal Building

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Figure 1: Rendering of A.J. Celebrezze Federal Building with façade over-clad. Courtesy of Interactive Design | Eight Architects.

Over the next several years, the A.J. Celebrezze Federal Building, located in Cleveland, Ohio, will be over-clad with a new glass and metal curtain wall. The façade over-clad will create a new exterior double-wall, using the existing original aluminum mullion, glass window, and stainless steel panel curtain wall system as the inner wall of the new system (*Figure 1*). Overall, the new façade will significantly reduce the amount of energy used for heating and cooling. An outrigger and girt system consisting of structural steel framing will support the new skin and withstand the demands of wind, blast, as well as thermal loads. The new curtain wall support will be installed from the building exterior, with minimal disruption to the building tenants.

The Structural Elements

The 33 story office building, completed in 1967, relies on steel moment frames in both directions and a reinforced concrete core extending up through the 13th story to resist lateral loading. Perimeter steel column and spandrel beam framing are encased in concrete for fire protection only. Story heights are typically 12 feet 6 inches, extending to a total building height of approximately 420 feet above grade.

The existing façade is an aluminum mullion, glass window, and stainless steel panel curtain wall system. The new glass and metal curtainwall system will be placed approximately 3 feet beyond the face of the existing façade (*Figure 2*). The glass of the new curtainwall will be treated with a frit pattern to reduce direct glare and heat loss on the building systems. One aspect of the façade over-clad involves replacing the original vision glass. For access to maintain and clean the double wall cavity, the existing windows at three locations on each floor will be replaced with an operable window.

Figure 2: New glass-and-metal façade over-cladding existing façade (background). Courtesy of Interactive Design | Eight Architects.

A steel outrigger-and-tube girt system was designed to support the new façade that will be outboard of the existing curtainwall system (*Figure 3*). The outriggers consist of a built-up tee section connected to the existing steel columns through the existing façade panels and concrete encasement (*Figure 4, page 28*). The stem of the tee extends perpendicular to the face of the building, with two additional flange plates that will sandwich a rectangular tube girt. The tube girt will span horizontally between the outriggers and parallel to the exterior spandrel beam. The tube outriggers are oriented to resist strong-axis bending under out-of-plane loading, and weak-axis bending under gravity load. The new façade connects to the girts with a blind bolt connection at the mullions.

The outrigger-and-tube girt system has been designed to accommodate the mill, plumbness, and position tolerances of the existing perimeter columns, as well as the fabrication tolerances of the new support tubes. The erected tolerances of the existing building structure were assumed to have met the AISC *Code of Standard Practice for Steel Buildings and Bridges*. The outrigger was detailed such that the built-up tee could be surveyed and set to the correct elevation. The top and bottom flange plates were sized to accommodate the expected out-of-plumbness tolerances of the columns. The girt-to-stem connection was designed as a field welded clip angle that could accommodate the expected gap between the tube and built-up tee.

The out-of-plane position of the girts developed into a struggle between architectural constraints and structural demands. The architectural and cost implication desire was to keep the girts as close to the existing building skin as possible. The structural design required out-of-plane strength and stiffness to resist the wind and blast forces. An outrigger-and-tube girt system was ultimately designed to satisfy the various design criteria, while maintaining the architectural constraints.

During erection, openings will be cut in the existing stainless steel façade panels and concrete encasement to weld the outriggers to the existing columns. To appropriately size the welds and check the base metal strength, material testing was performed to confirm the steel grade of the existing columns listed in the original structural drawings – ASTM A36 and ASTM A441 steel. Attachment of the tube girts, which are continuous, will follow the installation of the outriggers.

Temporary construction joints within the continuous girt are required to accommodate the range of temperatures that the girts may experience during construction. The tube girts will be exposed for at least a year before the new curtainwall is installed and the building enclosed. Consequently, the expected temperature variation in Cleveland throughout a full calendar year may vary from -30 degrees F to 130 degrees F. A series of temporary joints were designed to mitigate the

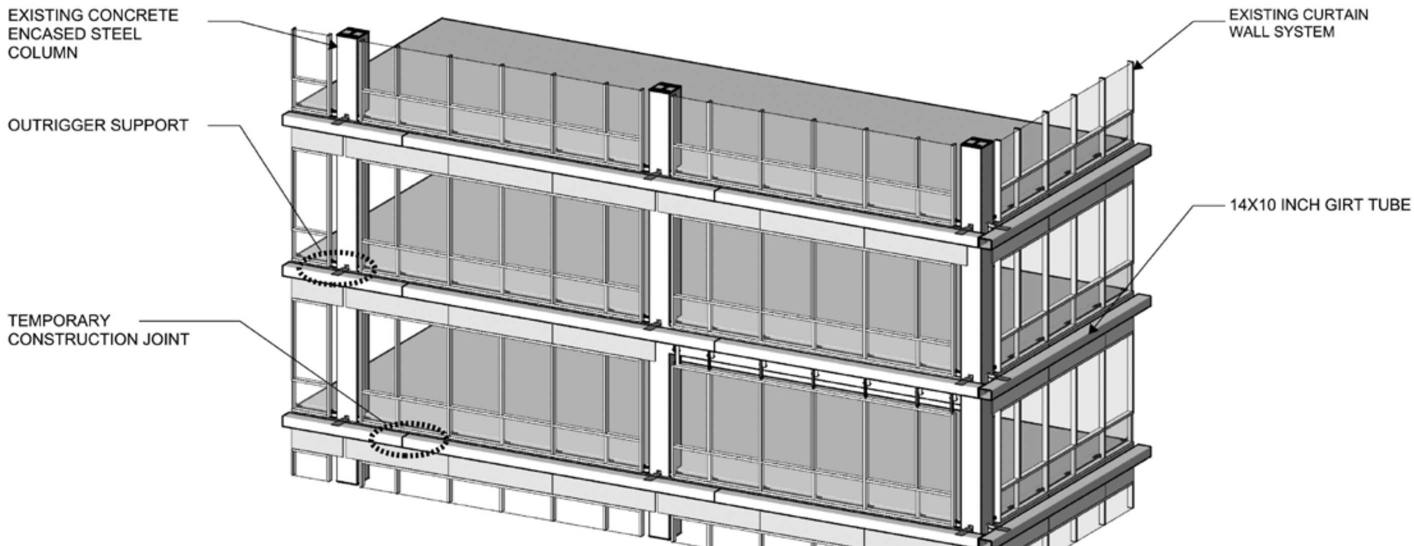

Figure 3: Rendering of outrigger-and-tube girt system attached to existing building. Courtesy of Thornton Tomasetti.

effects of the thermal load during construction and the capacity of the outrigger-and-tube girt in the final condition. The joints were located within seven feet of the outriggers, near the point of contraflexure under gravity loads.

Input from the contractor and steel erector led to the development of several alternates for the temporary construction joint. The joint required a complete joint penetration (CJP) groove weld to connect the adjacent tubes, and to establish continuity between the tube sections. However, due to the proximity of the existing façade, there was not adequate clearance behind the tube for a successful CJP field weld. A successful solution was developed through coordination with the contractor and steel erector that satisfied construction constraints and structural demands.

Design Loads and Performance Criteria

Main wind force resisting system (MWFRS) and components and cladding wind load criteria were obtained from wind tunnel tests of a 1:300 scale building model. The new double wall façade increased the surface area of the office building by approximately four percent, which was an expected increase in demand. However, the wind tunnel study yielded pressures that were approximately double the original design wind pressures at several localized areas of the building elevation.

Blast loading and performance criteria were provided by a blast consultant in the form of pressures with corresponding impulse magnitudes based on building risk and hazard criteria.

Two thermal load cases were considered – an operational load case and a construction load case. The construction load case was based on the expected temperature variation in Cleveland throughout a full calendar year, as indicated earlier, as well as the timing of certain construction operations that would introduce additional restraint to the system. The operational load case considered the temperature variation in the cavity wall – 30 degrees F to 115 degrees F – established by a computational fluid dynamics (CFD) analysis conducted by the mechanical engineering consultants.

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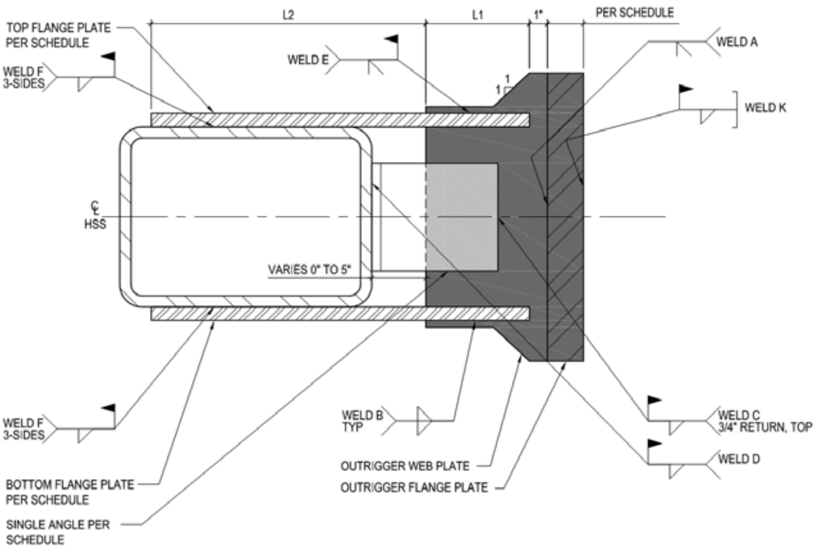

Figure 4: Typical outrigger connection to existing concrete encased steel column. Courtesy of Thornton Tomasetti.

In addition to strength demands of blast and thermal loads, the support girt design also had to meet stringent serviceability requirements. Allowable deflection limits for the new facade were specified by the curtainwall design consultants for wind and gravity load. However, the design was controlled by inelastic deflection limits set by the blast consultant.

Analysis and Design

The existing building superstructure and foundation were modeled in ETABS© to evaluate the existing building frame for the new curtainwall weight, updated design wind pressures, and current building code seismic load. The outrigger-and-tube girt design was an iterative process that considered various load cases for blast, wind, thermal, and construction.

For the blast design of the girts, a non-linear elastic-plastic dynamic analysis was performed on a single-degree-of-freedom model of the tube. The blast load was idealized as a triangular impulse load. Continuity of the tubes at the support locations were required to satisfy the blast performance criteria. The tubes were either HSS14x10 sections or built-up 14x10-inch tubes, with wall thicknesses varied to meet the blast load intensity. Concrete filled tubes were used to reduce the girt response where unfilled tubes yielded an undesirable response in regions of high blast.

The outriggers and tubes were modeled separately in RISA 3D© at each elevation to quickly assess the outrigger flange plates and built-up tee section. The outrigger was specifically modeled to reflect the variation in stiffness of the outrigger from the girt to the existing column. Component dimensions, plate thickness, and steel grades of the flange plates and built-up tee were adjusted in each model until the outrigger had sufficient capacity to satisfy all of the load combinations.

The construction load case analysis evaluated the outrigger-and-tube girt system for the combined effects of the welding sequence to close the temporary construction joints and withstand the thermal loads. The study revealed that the capacity of the tube girts and outriggers in the final condition were sensitive to steel temperatures during certain welding sequences. To communicate the findings to the contractor, allowable temperature ranges for welding were provided for various scenarios that could occur during construction.

The structural engineers chose to use up to 100 KSI yield strength steel for the outriggers. This enabled the built-up tee shapes to be as flexible as possible in-plane to minimize stresses due to temperature variation, while affording a robust shape to withstand large blast force effects.

A customized spreadsheet facilitated the design of the welds for the outrigger, the outrigger-to-tube connection, and the outrigger-to-existing column connection. Hand calculations of fully designed connections were used to verify the results computed by the spreadsheet. Design forces for the connection design were imported from the analysis program.

The building frame analysis results indicated that the existing steel superstructure had adequate strength to support the weight of the new curtain wall combined with the design wind and seismic loads. The outrigger-and-tube girt system was ultimately designed to accommodate the various design criteria, while meeting the architectural constraints.

Conclusion

The over-cladding of the A.J. Celebrezze Federal Building presented unique engineering challenges. Aside from normal loading and design conditions, the erection procedure of the outrigger-and-tube girt system had a large influence on the final design. Additionally, great care was taken to accommodate tolerances of the new and existing construction. Ultimately, a thoughtful design was developed addressing a variety of design issues. Construction for the new curtainwall is scheduled to begin in the summer of 2012.▪

Project Team

Structural Engineer of Record: Thornton Tomasetti, Chicago, IL
Building Owner: U.S. General Services Administration
Architect of Record: Interactive Design | Eight Architects, Chicago, IL
Blast Consultant: Hinman Consulting Engineers, Inc., San Francisco, CA
Curtain Wall Consultant: Curtainwall Design Consulting, Chicago, IL
MEP Engineer: Jacobs, Chicago, IL
Contractor: DCK North America, LLC, Pittsburgh, PA
Construction Manager: Gilbane Company, Cleveland, OH

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