Model Fidelity between Automated Simplified Model and Full FEA Model as Compared in SAP2000

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Abstract

For a confidential project in the US [permission to name project contingent upon acceptance of paper], Thornton Tomasetti (TT) was retained as the Engineer of Record (EOR) for the façade system. The façade design is an undulating, curved form made from bespoke molded Fiber Reinforced Plastic (FRP) and supported off the main structure by cold-formed steel trusses. The trusses are largely straight members, and the curvature in the FRP panels is accommodated by a curved cold-formed element in the front of the truss and bespoke connections between that respond to the curvature of the panel.

The main challenge of TT's scope was to automate the generation, analysis, and documentation of thousands of members in order to shorten the contractor's process time. Rhino Grasshopper was used to create a route that built trusses based on: section boundaries, available support points, span, and FRP curvature. A machine learning routine was employed to pre-estimate the ideal depth of truss and performance of different cold-formed sections. The truss models were linear analysis, and had a short solving time. The member forces from SAP were automatically fed into an Excel sheet that, with a macro calling an automation module of a specific cold-formed steel software, calculated the Design Capacity Ratio (DCR) of each member.

While this solved the question of time, the responsibility of TT as EOR necessitated that the automated and simplified models must be adequate to represent a full FEA model with all elements explicitly defined.

Two models were made for this study. The "full" model contained a surface mesh with accurate FRP properties, stainless steel threaded rods to connect the FRP to the exterior curved beam element, rigid links to connect the curved beam to a straight vertical "king post" member, which connected to the exterior chord of the truss via "ball joint" connection (itself modeled as a link with some rotational releases). Loads were applied as pressure to the surface mesh.

The "simple" model created through automation only included the truss members and the links representing the ball joint – the end of which the nodal loads were applied. The automation process made some assumptions regarding tributary area and load magnitudes, resulting in nodal loads.

After running both models, a comparison was made. First, the base reactions per models was checked. These were tightly aligned, with the exception of wind loads, as the mesh area is more efficient with distributing loads accurately. Then, the member force distribution was studied per load case. In both models, the maximum values were occurring in the same members, though the magnitude almost always was higher in the simple model. Deflected shapes per load case were compared, and found that the stiffness matrix of both models was very similar, with the exception of a thermal cases where the FRP mesh had a restraining effect on the steel. Lastly, both models' truss members were run through the DCR check, and it was found to be highly similar per member. When a member experienced a DCR greater than the allowable, it was present in both models.

In conclusion, as a result of this study, the design team was satisfied with the fidelity between the full and simple models and thus was able to move forward with the automated models with confidence.

References

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