Get Rid of all that Stress

Uni-Systems

By Bart Riberich, P.E., BSCE, MSCE, V.P. Engineering

We hear a lot about the harmful effects of too much stress in our every-day life. Owners, Designers, and Constructors of retractable roof stadia can benefit greatly from taking heed of this advice and applying it to the design and construction of retractable roof systems. Integrating stress relief mechanisms into the retractable roof design may be the single most beneficial decision a design team can make. These stress relief mechanisms can generally be grouped into two categories; suspension systems for distribution of gravity loads and thrust release systems to eliminate lateral loads. The following brief discussion focuses on the importance and benefits of integrating thrust release systems into mechanized roof structures.

When a design team begins schematic design of a retractable roof sports venue, they are undertaking a challenge that very few designers have successfully conquered. These mechanized structures are a significant design challenge because they fall outside the norms of both conventional mechanism design as well as conventional structural design. Mechanism designers usually work with precision made, small elements and thus thermal expansion, construction tolerances, structural deflections, and thrust loads from frame action are not usually significant design considerations. Likewise, structural engineers typically do not have to consider the tight tolerances required for moving parts nor the economic consequences of transferring high thrust loads through mechanisms. Therefore it is clear that the design of retractable roofs for sports venues presents unique design challenges that must be addressed with innovative solutions.

Obviously, the ultimate goal of the design team is to design a system that optimizes aesthetics, economy, safety, mechanical reliability, and ease of operation. Some externally applied lateral loads such as wind and seismic are unavoidable and simply must be taken by the roof drive system and structure down to the building foundation. However, other thrust loads are undesirable and avoidable. In order to attain the ultimate goal stated above, the roof design team must be keenly aware of the potential sources of these undesirable thrust loads. These sources of undesirable thrust loads include thrust reactions resulting from rigid frame action as well as lateral loads generated from the normal variations in the geometry of buildings associated with thermal expansion, structural deflections, foundation settlements, and normal construction tolerances. See Figures 1 and 2 for illustrations of thrust load sources.

Rigid frame action and attempting to restrain the geometry variations described above can generate thrust loads several times greater than those imposed by externally applied wind or seismic loads. The bearings and flanges of the wheels designed and installed to take the gravity loads have limited thrust load capacity. Thus it is simply impractical to burden the roof drive mechanism with any more thrust load than is absolutely required. In the past, attempting to take these extraordinary thrust loads has driven designers to use a separate system of wheels and rails to take thrust loads. These thrust wheels and rails are typically oriented 90 degrees from the orientation of the gravity wheels. At best, this has resulted in an unnecessarily difficult system to build and an unnecessarily high system cost. At worst, this has resulted in problematic and unreliable system operation.

The preferred design approach is, of course, to eliminate the undesirable thrust loads and design the system to accommodate only the more modest thrust loads generated by externally applied wind and seismic forces. Typically, the thrust loads generated by externally applied loads can easily, safely,

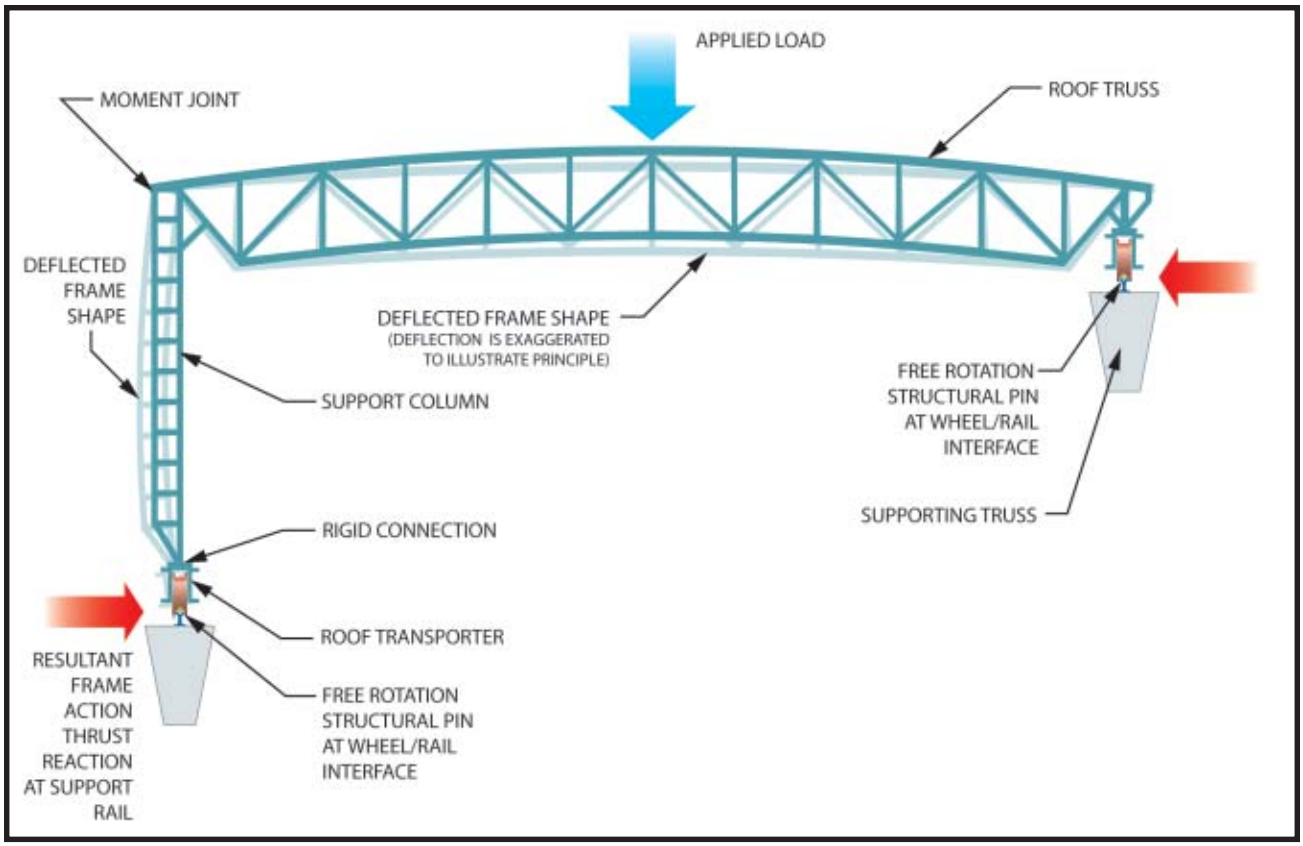

Figure 1 - Frame Action Thrust

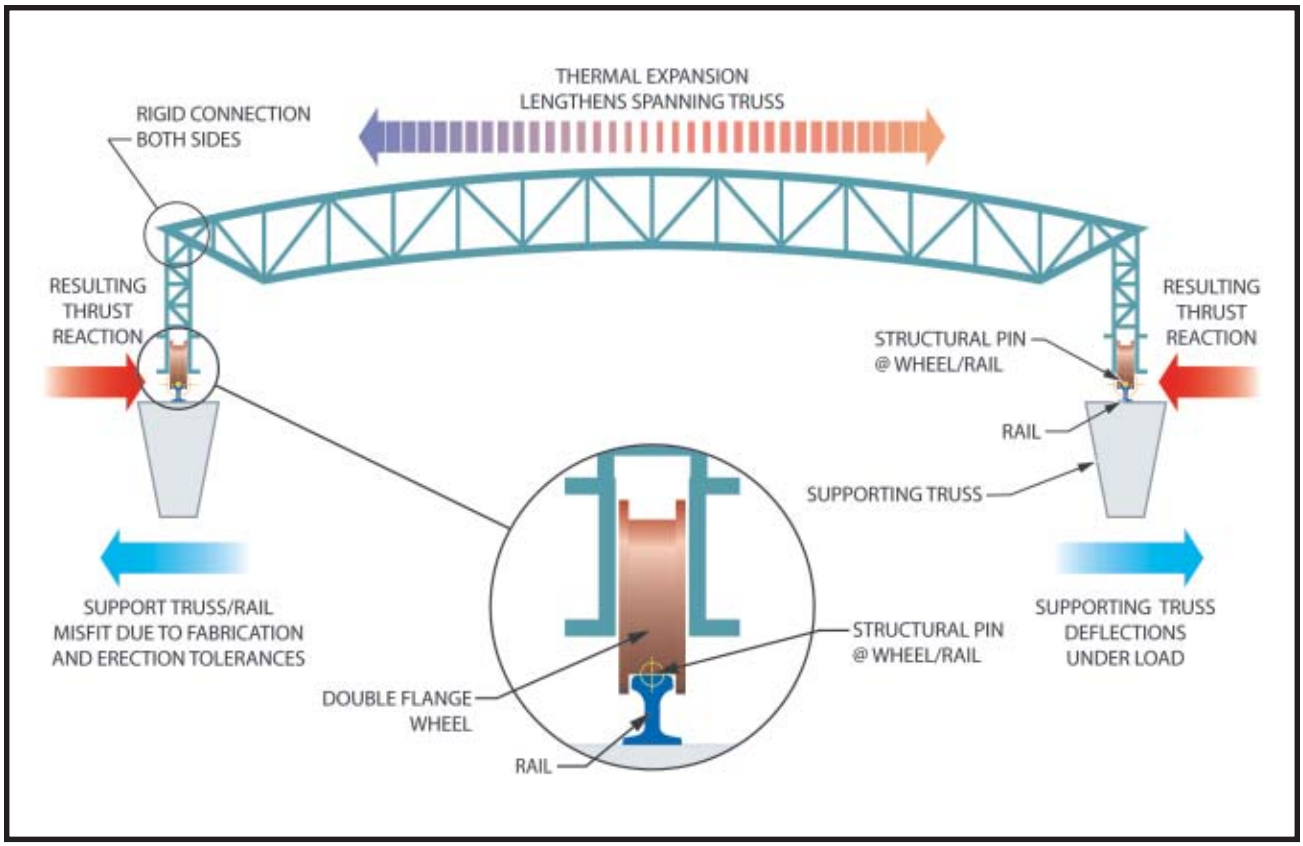

Figure 2 -Thrust Reactions from Geometric Variations

and cost effectively be distributed from the roof structure to the supporting structure via the flanges of gravity wheels riding on vertically oriented rails.

By adding strategically located release mechanisms in the system, the elimination of the undesirable thrust loads can be effectively accomplished without sacrificing economics, aesthetics, safety, or mechanical reliability. If properly done, integrating these release mechanisms can also provide the added benefit of significantly relaxing construction tolerances and thus beneficially impact the overall cost of the structure. See Figures 3 and 4 for examples of the integration of thrust release mechanisms into a structure.

Figure 3 is a schematic representation of the thrust release mechanism used in the roof structure of Minute Maid Park (formerly known as Enron Field), the home of the Houston Astros. The Engineer of Record, Walter P. Moore, integrated a structural hinge at the top of the tall vertical wall on the west side of the structure. This hinge was designed, tested, and manufactured by Uni-Systems. A second structural hinge is provided at the interface between the wheel tread and rail head in the transport system. The head of the rail is crowned and thus the wheel tread can pivot up to about two degrees on the crowned head with no detrimental effects. These two hinges allow the west end of the roof truss to move freely without generating stresses. This eliminates any thrust at the transport wheels from frame action, thermal expansion, and geometric variations due to structural deflections and construction tolerances.

Figure 4 is a schematic representation of the innovative thrust release mechanism incorporated into the roof design of Reliant Stadium, the home of the Houston Texans and the Houston Livestock Show and Rodeo. The Reliant Stadium design, as conceived by architects HOK Sport and Houston Stadium Consultants, presented significant lateral release challenges. The roof structure was designed to ride on rails that were supported by a supertruss that spanned 675 feet and thus could experience significant lateral deflections under load at mid-span. The design team also assumed that they could not expect the truss to be built to a mid-span lateral location tolerance of

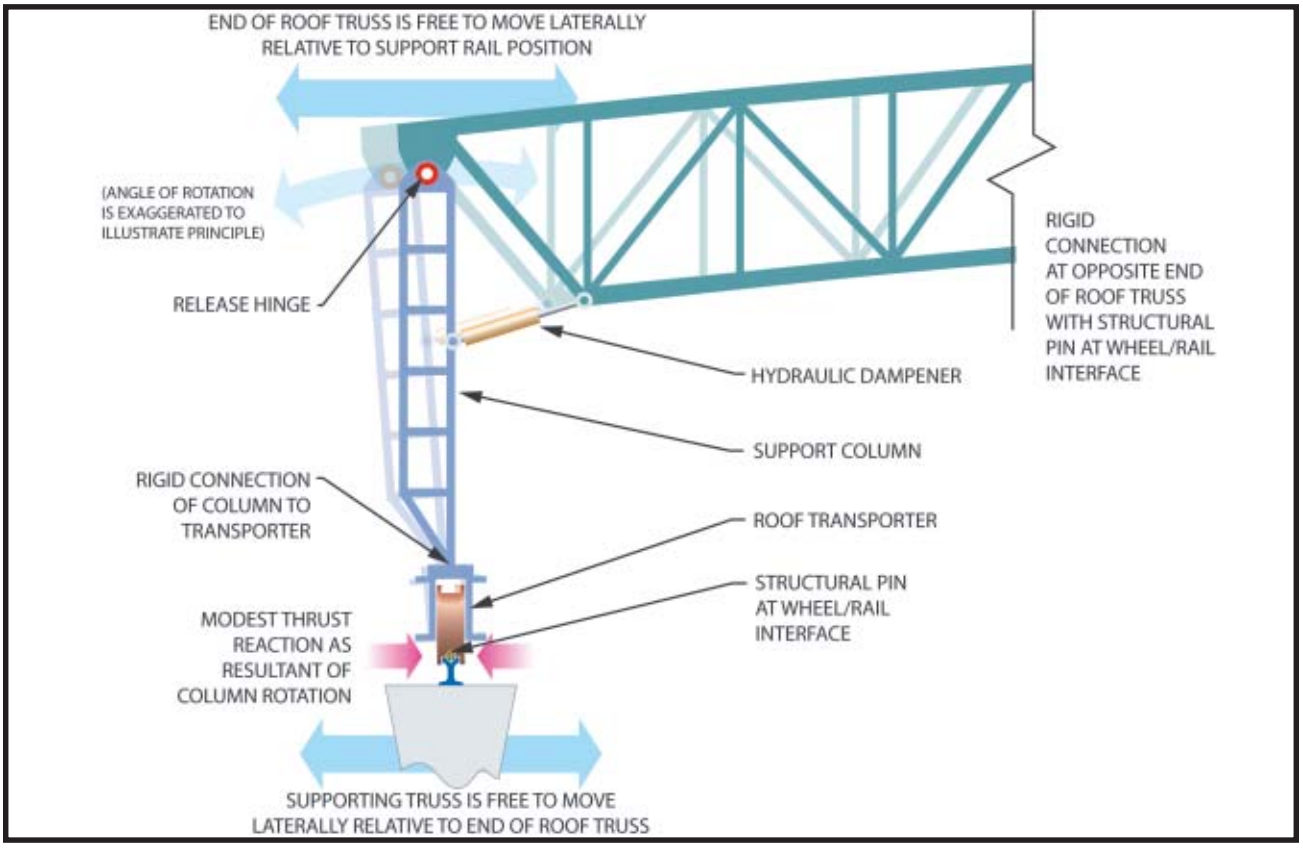

Figure 3 - Minute Maid Park Thrust Release HingeFigure 4 - Reliant Stadium 4 Bar Linkage

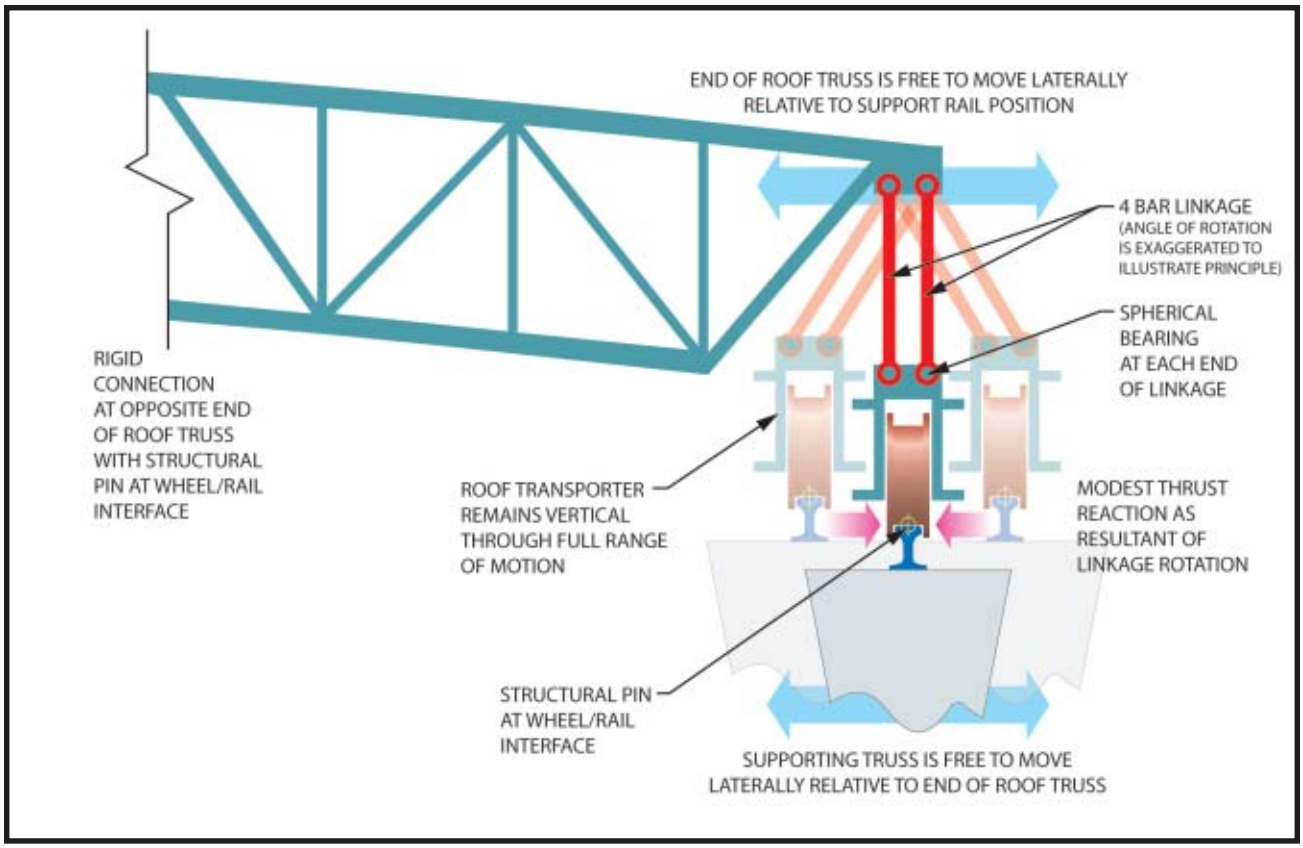

Figure 4 - Reliant Stadium 4 Bar Linkage

less than plus or minus three inches. When all expected tolerances and deflections were added up, the design team concluded that one end of the truss had to be able to move laterally plus or minus 21.5 inches relative to its supporting rail position.

This lateral motion had to be accommodated in a relatively short vertical distance of about ten feet. Thus, the hinge type release used at Minute Maid Park could not be used because it would generate an intolerable contact angle at the wheel to rail interface. Uni-Systems worked with the Engineer of Record, Walter P. Moore, to design and integrate an innovative linkage system into the roof structure. At the east end of the retractable roof tri-chord trusses, a four bar linkage was integrated to form the connection of the end of the truss to the transport carriers. This linkage allows free lateral movement of the east end of the retractable roof tri-chord trusses while keeping the transport carrier wheels vertical and producing only very modest thrust loads. Walter P. Moore designed the linkage arms. Uni-Systems designed, tested, and manufactured the maintenance-free linkage bearings. This linkage system provided an economical, easily constructed solution to a challenging design problem.

The examples provided above are a small sample of the many means of releasing undesirable thrust loads in structures. The challenge for the retractable roof design team is to develop the most economical and simple solution for the specific application being considered. Since every design is different, there are no generic solutions and that challenge is new for every design team. However, I hope that the information provided above leaves the reader with insight as to potential sources of unwanted thrust loads and a keen awareness of the need to eliminate them.

Remember, if you want your retractable roof to have a long and reliable life cycle, release those thrust loads and live the stress free life!

Uni-Systems