Structural Steel Economy: Revisiting the Assumptions

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Clarifying what is myth and what is reality when it comes to material and labor costs.

WHILE STEEL PRICES CONTINUE TO RISE AND FALL, responding to market factors, the basic cost equation of structural steel design remains the same: fabrication and erection labor exceeds material costs. Labor remains the largest piece of the puzzle, as illustrated in the chart on the following page. Furthermore, as the percentage increase in steel price is tracked over time, the data indicates that the percentage increase in labor costs has grown in proportion to other costs.

Structural engineers face a myriad of choices as they proceed through the design decision matrix for a project. As decisions are made, careful consideration must be given to use of materials, labor requirements, and schedule implications to deliver the most economical design—a goal that will be even more important in today's economic climate. There are several myths of structural design that have a tremendous impact on economy of design, and addressing them can help you make better design choices:

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Myth #1: Using less material reduces overall costs.

Design must consider material costs, but minimizing labor (in the shop and in the field) can improve efficiencies in the construction schedule and reduce total cost far more than weight reduction.

In general, designers can minimize labor in the shop by:

- Discussing fabrication/connection preferences with the fabricator (welding vs. bolting)
- Avoiding excess welding
- Allowing use of one-sided simple shear connections
- Reviewing member sizes as they relate to connection design. For instance, using the lightest member may require a web doubler plate or stiffener to carry the connection forces. Heavier columns and beams minimize reinforcing.

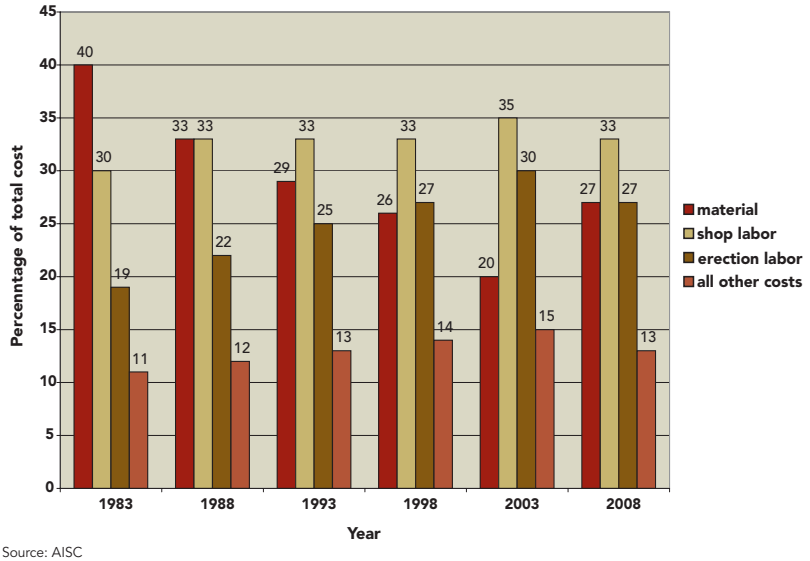
Designers can minimize labor in the field by providing:

- Simple load paths
- Systems that have inherent stability during construction
- Connectability
- Trade autonomy
- Trade interface
- Coordination between design and construction

Erection costs can be increased by using less material. For instance, lighter members (trusses and/or girders) may require additional shoring or erection bracing. This adds labor costs, equipment costs, and field time to the erector's schedule.

For example, during the design phase of the Mercy Hospital of Willard (Ohio) project for which Ruby+Associates was the structural EOR, our team considered using lighter members in several girders, which would have saved thousands of dollars in steel costs. However, when we looked at the big picture, these lighter members would have required shoring prior to placing the concrete, and the construction manager and erector determined it was not worth it due to additional scheduling complexity. In this case, the field costs outweighed the material savings.

Piece count also impacts fabrication and erection costs. Sometimes, in an effort to minimize materials, designers can increase the number pieces required in a structure. Each additional piece requires labor to fabricate, ship, and install, as well as connections at each end to attach it. Reducing piece count, even if material weight increases, can reduce overall costs by reducing labor and simplifying design.



Source: AISC

For example, a structural design with beams spaced at 7 ft, 6 in. on center equates to three beams per 30-ft bay. That's three pieces and six end connections for each bay. By redesigning the beam spacing to 10 ft on center, the count is reduced to two pieces and four end connections. This is a relatively small savings for a single bay, but buildings typically include multiple bays and multiple floors, causing this small savings to grow proportionally.

Design economy also can be achieved by grouping member size. This reduces fabrication costs, simplifies erection, improves quality, and shortens the schedule. This was the case in another medical project with which we were involved. Our original design for St. Vincent Mercy Medical Center Heart Pavilion optimized structural steel weight by using a mix of W18x35s with W21x44s. Our fabricator said it would be cheaper to use all W21x44 members, standardizing all connections and eliminating field confusion.

Myth #2: Designing connections for a percentage of UDL is a simple and effective approach.

Design should follow analysis, not necessarily an arbitrary percentage of the member capacity. As a designer, don't rely solely on the use of "50% of uniform distributed load (UDL)" for connections. Put reactions on design drawings and give fabricators a choice of how to design the connection.

As connection designers, we have seen some very short beams (which, with 50% UDL rule, equate to a very large connection force) require full-depth bolting and web doubler plates at the connections. We suggested designing for the actual member end reaction and were able to eliminate all of the doubler plates, reducing costs significantly.

With today's analysis and design tools, it is easier than ever to provide beam end reactions and member forces on the design documents. This information is invaluable to the steel construction team during the bidding and delivering of projects.

Myth #3: Increase design complexity to reduce material costs.

Increasing design complexity to reduce material costs may actually end up increasing total project costs. Schedule is part of cost; simpler buildings go up faster, reducing labor costs. Design complexities can be reduced by incorporating:

- ➜ Simple load paths
- ➜ Simple connections
- ➜ Simple fabrication
- ➜ Simple erection

Apply the "KISS" principle: Keep it simple, stupid. Increasing design complexities in labor-intensive areas (such as steel erection and fabrication) in an attempt to reduce material costs addresses the wrong side of the equation. Design should not reduce materials at the expense of labor. Design time should be invested in identifying ways to reduce the labor side of the equation to save project time and money.

Myth #4: Construction methods are not a design concern.

With labor costs accounting for more of the structural construction costs, it is very important for a designer to understand how their building will be built. This understanding and knowledge is a valuable tool to help in making good design decisions. Construction methods directly impact labor costs and schedule.

As a designer, eliminate and minimize:

- ➜ Beam copes
- ➜ Doubler plates
- ➜ Stiffener plates
- ➜ Skewed connections
- ➜ Full moment connections
- ➜ Full-capacity column splices
- ➜ Large beams framing into small beams

During design, consider:

- ➜ Site constraints, access, and lay-down areas
- ➜ Temporary bracing shoring requirements
- ➜ Approaches to minimize field welds

If possible, talk to the fabricator, connection designer, and erector to get feedback on your design approach. Factoring coordination of the other structural parties into the design matrix can significantly shorten a construction schedule—sometimes by bringing significant changes to the design. Working with a fabricator/erector during design and construction of a multi-story facility, we recently suggested a design modification to use a steel core instead of a concrete core. A concrete core would have taken significantly more time to construct in the field, extending the schedule. A steel core was mostly shop fabricated and required less field time.

In addition, when steel members are framed into, or supported by, masonry or concrete, then (depending on how they interface) one trade may be waiting on another trade in the field, or—even worse—interfering with their progress. So coordination with non-structural trades is a good practice to follow as well.

Balancing Costs

When designing a structure, the design matrix must balance material costs, labor costs, and schedule to deliver the most economical design. As the construction industry continues to be challenged with tough economic conditions, this holistic approach to design will become a mandatory element in moving projects forward. MSC

Ten things to remember when designing steel projects:

- ➜ Least weight isn't always least cost; least labor is least cost.
- ➜ Keep it simple!
- ➜ Heavier columns minimize reinforcing.
- ➜ Heavier beams minimize reinforcing.
- ➜ Design connections for actual reactions.
- ➜ Allow one-sided connections.
- ➜ Don't over-weld!
- ➜ Specify the correct bolt for the job.
- ➜ Integrate your design.
- ➜ Understand how your building will be built.