THE PROGRESSION OF THE STRUCTURAL ENGINEER

What is truth? An experienced structural engineer found that when it comes to design, truth changes over time.

BY ERIK NELSON, P.E., S.E.

THERE SEEMS TO BE A PROGRESSION of understanding throughout the life of a structural engineer. In my case, as a college student I think I was drawn to engineering because it seemed to be an entirely rational field of actual correct answers to problems. It gave me well-defined analytical techniques to arrive at a certain beam or column size.

But this idea of "truth" and "correct" answers proved naïve. Structural design is not as clean as I had thought. The problems I solved in homework assignments were not similar to the problems encountered in practice. Today, I can look back at my design career and see a certain progression of understanding, an improvement in design skills resulting from a raised consciousness. As an engineer's career progresses, he realizes that the problems he encounters are not simple, but complex and nuanced, and require experience to better sift through their multiple solutions; there is never just one!

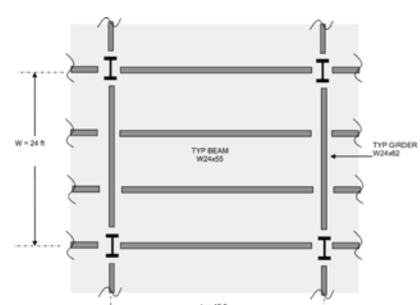
I think this idea of progression is similar to the one that the philosopher Friedrich Nietzsche wrote about in *Twilight of the Idols*. While Nietzsche was generally referring to raising the human spirit to a higher level, this is similar to my experience as a structural engineer over the past decade.

To better understand this progression, let's use the example of designing a steel floor system. We'll solve for various designs using the same assumptions: 24-ft by 42-ft interior bay with a 3¼-in. lightweight concrete plus 3-in. metal deck supporting a 50-psf live load and a 20-psf superimposed dead load. In this scenario, the structural designer's progression of understanding—from engineering student to principal—may go something like this…

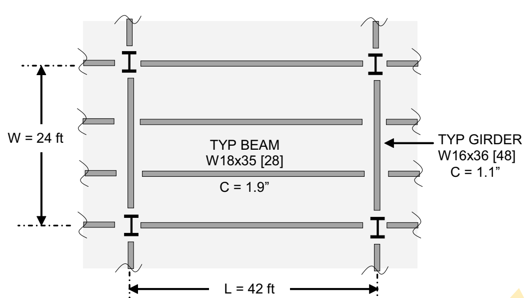
1 Structural design to an engineering student:

Structural design is nice and exact. That is, given the length, loading, and other assumptions of a particular beam, I can design it and actually have a correct answer. Structural design is wonderful and objective, not so touchy-feely like the arts. W24×55 is the answer, period.

"The truth of structural design—Attainable for the sage, the pious, the virtuous man."



The "Pious" Design
The design neglects use of composite action, which was not included in the student's steel or concrete class. The student did check deflection however, and found the beam to be controlled by it. Overall, the design is too heavy and costly.



The "Virtuous" Design
The engineering graduate uses composite action and pushes the limit of precomposite dead load deflection. The exactness of the beam camber is academic and too exact. The deep beam framing into a shallow girder is, in a word, ugly. This design shows signs that it came from computer output that was not reviewed. The shallow girder may lead to future vibration problems. Overall, the design is not practical.

2 Structural design to an engineering graduate:

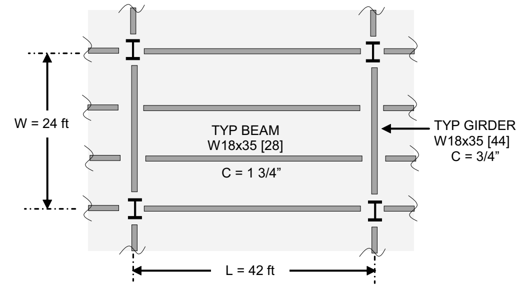
Structural design is harder than I thought. I have to understand unbraced lengths, deflection limitations, vibration, and modeling assumptions. I also need to study up on steel connections, coped flange shear capacity reductions, composite beam design, camber, stud capacity and count, lower bound moment of inertia for deflection, etc. I'd better hit the books!

"The truth of structural design—Unattainable for now, but promised for the sage, the pious, the virtuous man."

3 Structural design to an engineer-in-training:

Structural design isn't as exact as I thought. This floor system doesn't seem to make sense when only optimizing for strength. The best design in terms of steel tonnage could be a deep beam that frames into a shallow girder, but that doesn't "feel" right. Maybe I should also think about repetitive use of beams, or maybe I should think about piece count (crane time). I might not have the exact answer, but I'd better get close!

"The truth of structural design—Unattainable, indemonstrable; but the very thought of it, a consolation, an obligation, an imperative."

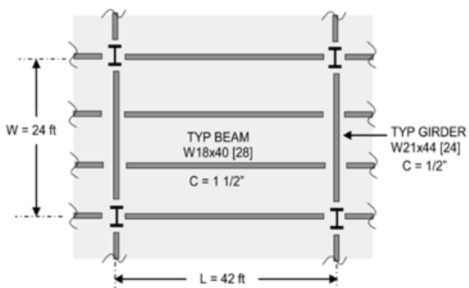


The "Obligated" Design
Camber is in increments of ¼ in. for now, but may become excessive and lead to problems with floor leveling and over-camber. This designer values repetitive use of beams (or perhaps values double copes). The girder has more studs than one per decking rib, which requires a stud reduction factor R_g = 0.85. Also, the floor may lead to undue vibrations. Overall, the design is risky.

4 Structural design to an engineer:

Can I design a steel floor system using certain optimization criteria (tonnage, piece count, repetitive sizes, etc.) and get close to a "correct" answer? I can create a matrix and weigh tonnage, piece count, and repetitive use of similar beams. But which to give the most weight? Maybe the best design has to do with how I weigh each criterion. Is that it? Who knows?

"The truth of structural design—Unattainable? At any rate, unattained. And being unattained, also unknown. Consequently, not consoling, redeeming, or obligating. How could something unknown obligate us?"

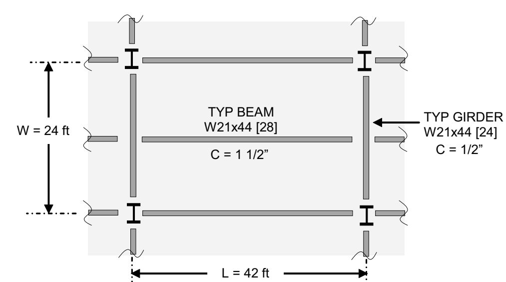


The "Unattainable" Design
The beam camber is more reasonable and the girder now has only one stud per foot. Although this engineer decided that "truth" is unattainable, he or she got pretty close. The floor frequency is better and there is less likelihood of having problems with over- or under-camber in the field, although some engineers feel that beams should not be cambered if they are less than 30 ft long. Overall, the design is okay.

5 Structural design to a senior engineer:

The criteria for structural design are becoming too subjective, not like the good old days. Should the beam be cambered at 30 ft long? What percent composite shall I assume? Maybe I should try to stretch my composite slab to 12 ft instead of the standard 10 ft. Should I use live load reduction for beams, or just for columns? You do it your way and I will do it mine.

"The truth of structural design—An idea that is no longer good for anything, not even obligating, an idea that has become useless and superfluous—consequently, a refuted idea. Let us abolish it!"

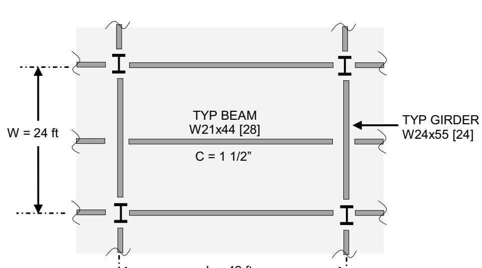


The "Abolished" Design
The slab span changed from 8 ft to 12 ft, pushing the limit of the 6¼-in. slab for the unshored condition. This results in a lower piece count and less tonnage. Some designers may feel uncomfortable with a 12-ft slab span, but the design appears economical. The girder stud count is high. The floor system frequency is a bit low at 4.1 Hz, but is okay. Overall, the design is pretty good.

6 Structural design to a principal (the final progression):

Structural design is tricky and requires a lot of experience to get right. One particular framing system is chosen not because it is the truth, but because it is "practically the truth." And "practically the truth" is enough to discover that one system is better than another. You see, structural design is really not objective. There really isn't one answer; there never has been. The problem is that design is perceived that way and has an objective truth assigned to it. Once you abolish this misconception, the creative possibilities are once again limitless.

"The truth of structural design—We have abolished. What world has remained? The apparent one, perhaps? But no! With the true world we have also abolished the apparent one."



The "Not-So-Apparent" Design
The girder was upgraded to a W24×55 so as not to require camber and to reduce risk of excessive deflection and vibration. This is an increase of 0.3 psf in the steel tonnage from the system in stage 5, but the payoff is well worth it. It also anticipates possible 12-in.-deep web penetrations. This appears to be the best design of the six and is economical (a full 1 psf lighter than the system in stage 4). Overall, the design is good.

Six Degrees of Floor Design

All six of the framing schemes work and all six have the same bay size and loading assumptions. Thus, it is apparent in this progression the great extent to which the individual engineer can influence the design. I have found that the design of structures is less dispassionate and logical than I used to think earlier in my career. Subjective terms in structural engineering (good, ugly) can and should be used alongside objective ones (0.3-in. deflection, 5 psf), because many of the problems we face become subjective—and that is a good thing. I think this arises from the fact that there are no clear-cut answers to the complex and diverse problems we face. This is not to diminish the role of analytical tools to assimilate knowledge of phenomenon (or of steel), it is just these tools are simply not enough. MSC

All quotes are from Twilight of the Idols *by Friedrich Nietzsche, translated by Walter Kaufmann and R.J. Hollingdale, substituting "the truth" with "the truth of structural design."*

Erik Nelson is a structural engineer with Odeh Engineers in North Providence, R.I. and an adjunct professor at Rhode Island School of Design.

Here, he and son Kinan illustrate the progression of man—from thumbs to coffee.

For comments related to this article, he can be reached at ean@eandesign.com.

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