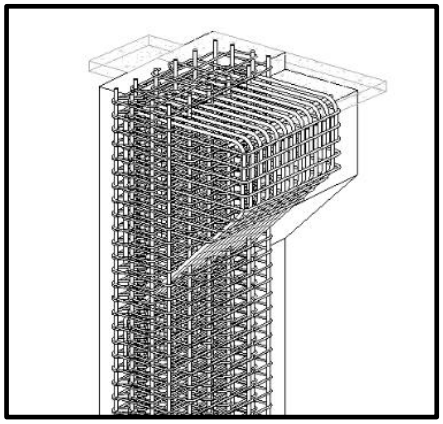
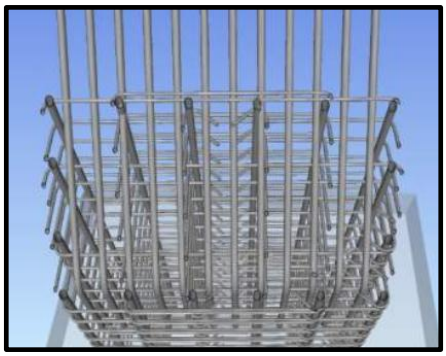
Sweet Spot for Cost of Failure

Executive summary. Both engineering failures, and *the prevention* of engineering failures, can have extraordinary costs. These costs can be financial, reputational, time-related, or even fatal. There's a sweet spot to knowing what is too much engineering and what is too little engineering. Can we find the sweet spot?

Preventing failure should come at any cost. Uh, no. The world cannot afford to engineer every structure to not collapse from a 5,000 mph meteor the size of New York City. However, design codes and engineering know-how can prevent the vast majority of failures based on strength of materials and probability. This is why we have building codes. And this is how design methods have morphed from the earlier days of ASD (allowable strength design) to the more recent LRFD (load and resistance factor design).

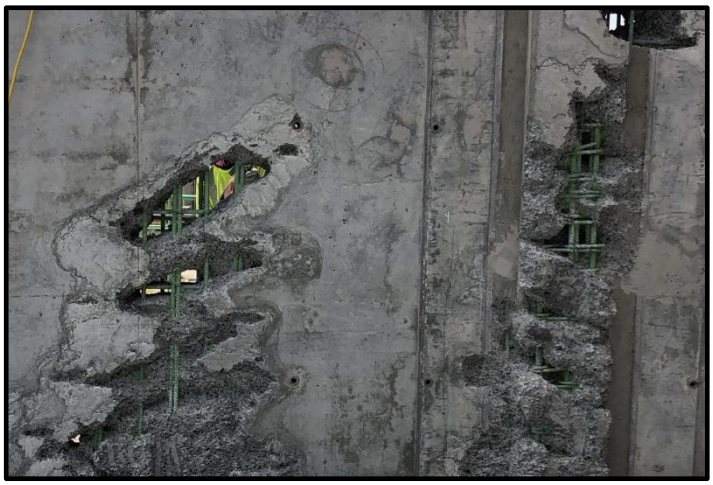


Column/corbel: where do I put my concrete? How is the contractor going to get concrete in here? With no room for a concrete hose, how will the contractor comply with maximum freefall limits?



This looks almost like a soil sieve, or a "grizzly", with only 1 1/4" clearance between the twelve (12) bars at the top of the graphic. Good luck on maintaining a consistent matrix of cement and aggregate.

"We can't make things too safe – be conservative." I'm not sure about that. It's a slippery slope, this article, for sure, but, are some things too safe? Are structures overdesigned? Is there too much rebar in a structural element when the contractor has a hard time passing ¾" aggregate concrete through its steel matrix (see models and photos at left)? There's just so much steel – is it even engineering anymore? How are you supposed to actually



Elevation view of a reinforced concrete wall with rebar so dense that consolidation was not achieved.

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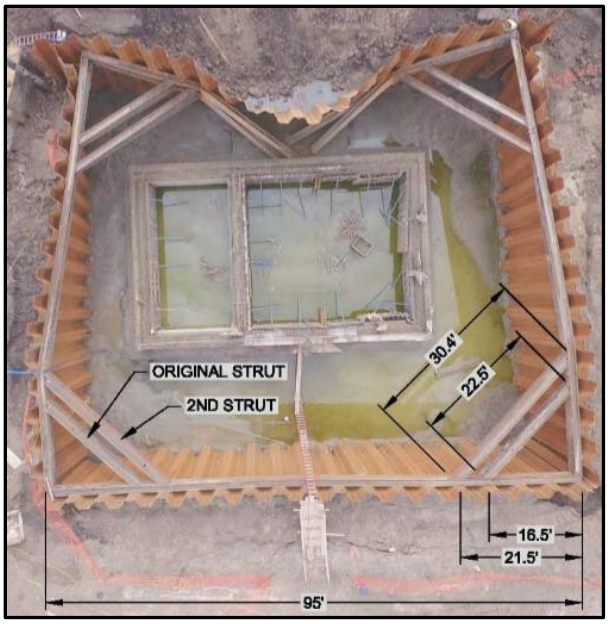
place the rebar and then get the concrete placed? Should we blame the engineer of record? Well, not really, because (s)he is just following mandated building code. So, should we then look to the engineering community who establishes the code? Perhaps.

Said a contractor: "Let's just wing it…it's close enough." Sure, this is another approach. And this is an option. This scenario is more likely seen in contractor designs where budgets are tighter and schedules are shorter. However, at the end of the day, a prudent contractor (and savvy owner) will ensure that a professional engineer is reviewing and sealing the work. And that should prevent failure, again, a vast majority of the time. Failure does occur when shortcuts are taken on design and/or construction as seen in the shoring failure on the right. (Nelson, 2022)



Failed shoring due to a failed design combined with poor craftsmanship. (Nelson, 2022)

Where is the sweet spot? These examples have shown what too much engineering can do to a project and what too little engineering can do to a project. Each of these approaches to the work are too expensive.

Being overdesigned costs money in too much steel, too many fancy and spendy design mixes, too many meetings between contractors and engineers to re-engineer to a constructable design, and then too much "repair" work to bring an unbuildable design into a scabbed together pipe dream of a well-intended final product (again, see photos and the model earlier).

Being underdesigned costs money in removal and replacement during construction, excessive maintenance during operation, and maybe even human injury at any time during a constructed facility's lifetime.

Two gentlemen created a wonderfully basic graph below to try to show where this compromise may exist. (Agaiby & Ahmed, 2016) At the graph's far left, you can see that too much engineering [described as "Principled engineering (overdoing)"] and being too safe is too costly. From the right side of the graph you can see that

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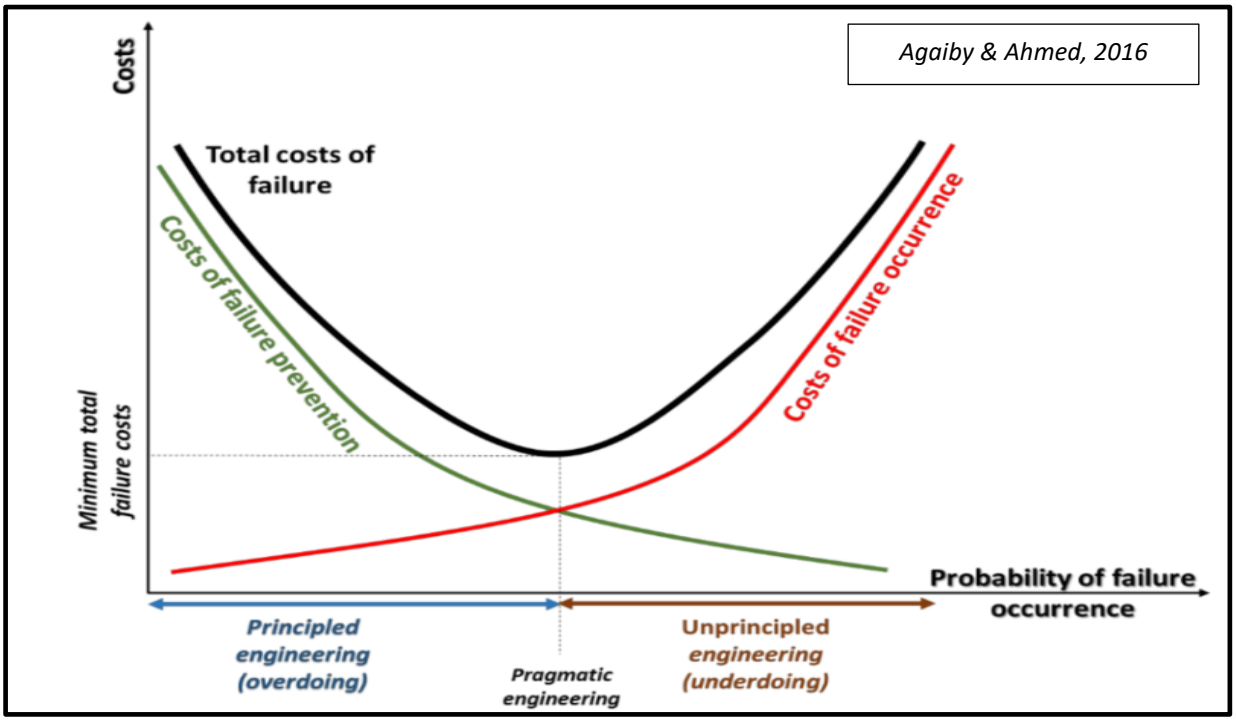

"underdoing" the design is extremely costly as well. The compromise to these two extremes is at the intersection of the two, and labeled as "Pragmatic engineering".

There is the sweet spot. At least on paper. Does it exist in the real world and how is it even measured?

My story. The rebar challenges above were from my own experience, while the sheetpile failure was pulled from a reading of mine. But, these failures, both over- and underdesigned, exist in all jobs. And most jobs seem overdesigned until a hurricane or a flood hits, and then everyone "gets it" – they get why all that rebar was in place or a berm was built to 100% compaction (instead of 90% or 95%).

I thought the graphic by Agaiby & Ahmed nailed it. But, I do have two modifications to it for consideration (see next page):

1. Time as an additional axis (in purple) – nothing really ever gets cheaper. So, there should never be a strategy of "let's wait until costs come down." Therefore, design should be done as quickly as possible and should not strive for perfection. Stop designing and get building.
2. Contractor-participation – call it design/build, progressive design/build, design assist, value engineering, whatever, but it is when the design is led by the builder. A contractor paired with a constructor-savvy engineer pushes the

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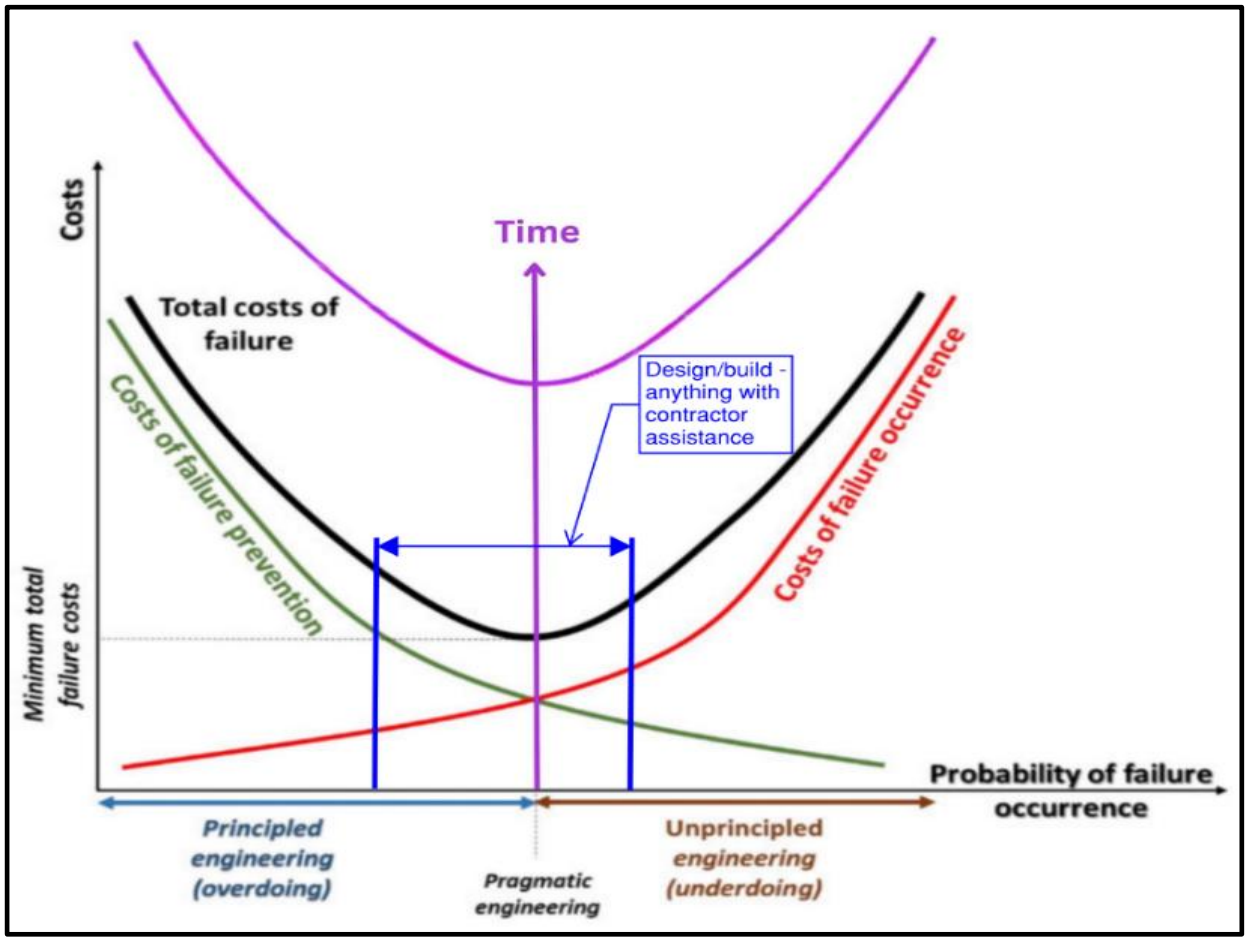

Modified chart by Agaiby and Ahmed, 2016. The purple and blue lines and text show effects of time and contractor participation.

limit on engineering by driving to the most cost effective design. And quickly! This is where pragmatic engineering comes into play and the sweet spot is as sweet as it gets!

The bottom line here is that, generally speaking, there's always a way to build safe infrastructure at a minimum cost. This can be done by an owner's engineer, but more often than not can be done by a contractor and his engineer, better. Consider it as an owner – and to my engineering friends, look for the sweet spot there in the "practical engineering" valley!

Work safe!

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Agaiby, S., & Ahmed, S. (2016). 0434-Learning from Failures: A Geotechnical Perspective. Proceedings of the International Conference on Forensic Civil Engineering. https://doi.org/10.13140/RG.2.1.3616.3602

Nelson, E. J. (2022). 0425-Evaluation of Shoring Wall Failure Irving, Texas. In R. Liu, C. C. Mulea, M. K. Parfit, & T. L. Cavalline (Eds.), 9th Congress on Forensic Engineering 2022: Elevating Forensic Engineering (pp. 232–240). American Society of Civil Engineers (ASCE).

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