Engineering Ethics: Conservatism in Engineering Design

An Online Continuing Education Course for Engineers

Course Number: ET-2004

Credit: 2 Hours / 2 PDH / 2 CPD

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Understanding the "Belt and Suspenders"

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Introduction

There are numerous methods, accepted practices, and accreditation entities that aid in making sure engineers graduate with the fundamentals necessary to work in today's professional world. From the first test issued in fundamentals of engineering class to the last question of the afternoon session of the PE exam, all engineers are trained and tested to think as engineers. Degrees and licensure confirm that individuals possess the basics, and to a certain extent, the aptitude to work and practice as engineers. Engineers learn the math, science, basic equations, and numerous other bits and pieces of information that arm them for engineering careers. The grasp of these fundamentals is often a direct indicator of a new engineer's trajectory and longevity in the professional world.

Engineers who have successfully made the transition from the classroom to the professional world are astutely aware of the multiple soft skills and uncommon knowledge they lack at initial start. They also know the different methods by which the industry can cause them to bear these "fruits of experience". Whether it is by ridicule or tutelage, engineers are forced to obtain those skills and knowledge and appreciate them. Those skills are what define engineers. Possession of these skills is what separates the good engineer from the mediocre engineers. Most engineers can readily recall that one particular engineer, project, or string of events that helped mold their career. One can almost guarantee that amidst all of those lessons learned and teachings that one thing stands out. It is that thing that is common to all engineers. It is the one thing that can make an engineer look like a genius or a buffoon. Conservatism. It is the necessary evil in the world of engineering.

Poll any number of engineers and you can be sure the majority of them will say that they had to learn "how to be conservative". There is no course taught on "how to be conservative" or "when and when not to be conservative". There are no set rules for being conservative or optimizing conservatism. Manipulating conservatism in engineering design can be considered a skill; almost an art form. The course Conservatism in Engineering Design was written to give engineers more insight in this area. It is intended to expose the engineer to conservatism and to develop an appreciation and understanding of its use and importance.

1.0 What are the Sources of Conservatism?

Before any deliverable is prepared, an engineer has to determine the basic inputs and required sources of information. To the green-horn engineer these basic inputs and informational sources are just that- inputs and sources, nothing more. However, to the more experienced engineer these are the main ingredients for success or failure. Engineers develop an appreciation for information due to a lack thereof in previous circumstances. This appreciation comes from knowing that these basic inputs and informational sources determine the size, shape, color, weight, and all of the other measurable quantities associated with deliverables. These inputs and sources contain the basis for either his/her success or failure. In other words, they will ultimately impact how conservative or un- conservative the final result will be. In order for the engineer to make an observation of this magnitude, the conservatism has to be identified at the source. These sources are design specifications, Engineering assumptions, Industry Standards and General Practice and Client or Vendor Provided Data.

Design Codes and Specifications

The majority of the design specifications published are industry specific and are intended to be used as guidance. The upper echelon of design specifications are not only industry specific, but they are also used as controlling guidelines with recommendations. The importance of these documents is to provide uniformity and consistency in safety and design. The American Institute of Steel Construction (AISC), American Concrete Institute (ACI), and American Society of Civil Engineers (ASCE) are all examples of entities which publish specifications to provide uniformity and consistency in safety and design. The American Society of Mechanical Engineers (ASME), National Fire Protection Association (NFPA), and other entities accomplish the same but are more stringent in some cases and can have legal ramifications for not using them properly. All of the documents published by these entities are compiled based on research, high level experiments and studies, as well as industry experience and knowledge.

The sources of conservatism become more apparent when you read the commentary associated with these documents. For design purposes, these types of documents include safety factors that are either factored in, applied to theoretical design values, or allowable values to be used for design. These safety factors can be reflected in the reduction of material strengths considered, and the modification of real life design parameters such as length, temperature, height, weight etc. Additional sources of conservatism in documents of this nature include load combinations or load cases. Oftentimes a prescribed set of loading conditions with factors applied to each load are used to provide conservatism. These combined loading effects are used to address the issues ranging from fatigue, environmental uncertainties, human errors in fabrication, and design probability and other intangibles.

The safety factors, load combinations and modifications of real life design parameters work in conjunction with code specified design equations. These design equations are often adapted from extensive research and known material behavior characteristics. The key to the conservatism associated with design codes and specifications is that they provide conservatism up front. Codes and specifications provide the conservatism necessary to address unknowns in regards to human error, material behavior and the uncertainty of environmental conditions.

Engineering Assumptions

Engineering assumptions as a source of conservatism are essential to the engineer since this is the source of conservatism where the engineer has the most input. The engineer has to make initial assumptions in order to provide deliverables! This is apparent because few deliverables are prepared, and hardly any design work is started without invoking some industry design code or specification. Most codes and specifications recommended maximum or minimum loads for design. In the majority of situations, it is the responsibility of the engineer to develop the primary loads. The engineer is responsible for determining the intended service of a piece of equipment, structure, component, etc. Even after the intended service has been determined, an engineer has to be aware of or anticipate how the structure, equipment or component will behave under certain loading conditions. All of these factors provide the basis for how conservative the engineer should be. The engineer's assumptions must work together to provide the level of conservatism necessary to ensure the deliverable provided is within expectations.

Standard Industry/General Practice

The conservatism associated with engineering assumptions and design codes can be considered regimented and more easily justified. This is true primarily because they can be documented and quantified. An all together different source of conservatism are Health, Safety, and Environmental Requirements. Requirements of this nature tend to focus more on individual safety and the conservatism contained in them comes as a by- product. Health, Safety, and Environmental requirements can often spawn a deliverable more conservative than intended due to more stringent requirements. Oftentimes a suitable design or deliverable may have to be more conservative due to safety requirements.

General engineering practice as a source of conservatism can be directly related to the industry of service. This is true because an engineer with nuclear experience will provide a totally different design than an engineer with a petrochemical background. Primarily because the nuclear industry is more conservative in nature due to Health, Safety, and Environmental requirements compounded with more stringent design code and specification requirements. In other words, what may pass for general practice in one industry may not pass for another.

An engineer's background with respect to industry, code knowledge and design experience develops their preference. It is not abnormal for engineers to add additional conservatism based on their preference or "gut feeling". Some engineers become accustomed to seeing certain situations handled or designed a certain way in the field or on a drawing. This will often lead to an experienced engineer changing a beam size or depth to a larger one, adding an additional support where it may not be needed per the design loads, so forth and so on. Engineering preference and experience as a source of adding conservatism should be used with caution. This source of conservatism can be welcomed in some cases and/or ridiculed in others. This is true because an engineer should always be able to justify, quantify or explain his logic or theory in support of a decision. It is what separates the engineers from the rest of the design team.

Client /Vendor Provided Input

All of the sources of conservatism previously listed can be compounded and included as a part of client or vendor provided input. Often there is no certain way to determine the level of conservatism of the input provided by external sources unless there is good documentation or a means of verifying the data. Vendor data is usually easier to verify due to the level of documentation required and publishing of the information. Most vendor products are designed and invoke industry standards, design codes and specifications. Some vendors even apply more conservative safety factors and go to extreme lengths in research to provide verification of their data. The engineer should put forth the effort to become aware of the conservatism included in client and vendor provided information. Not knowing how much conservatism is included prior to adding additional conservatism for whatever reason can result in over design.

Example

A rigging set-up is to be designed for 20 Tons (10 kips) with a safety factor of 1.5. A shackle manufactured by vendor "Company X" is to be selected from the table below.

Shackle Pin Size	Allowable Load (Tons)
0.75	3
1	4.5
1.25	6
1.5	6.5
1.75	9
2	12
2.25	15
2.5	20
2.75	22
3	26
3.25	30
3.5	34
3.75	40

Allowable Loads Contain Safety Factor of 2.75

Neglecting the safety factor per the vendor's published data; the required shackle will be selected for the load calculated as follows:

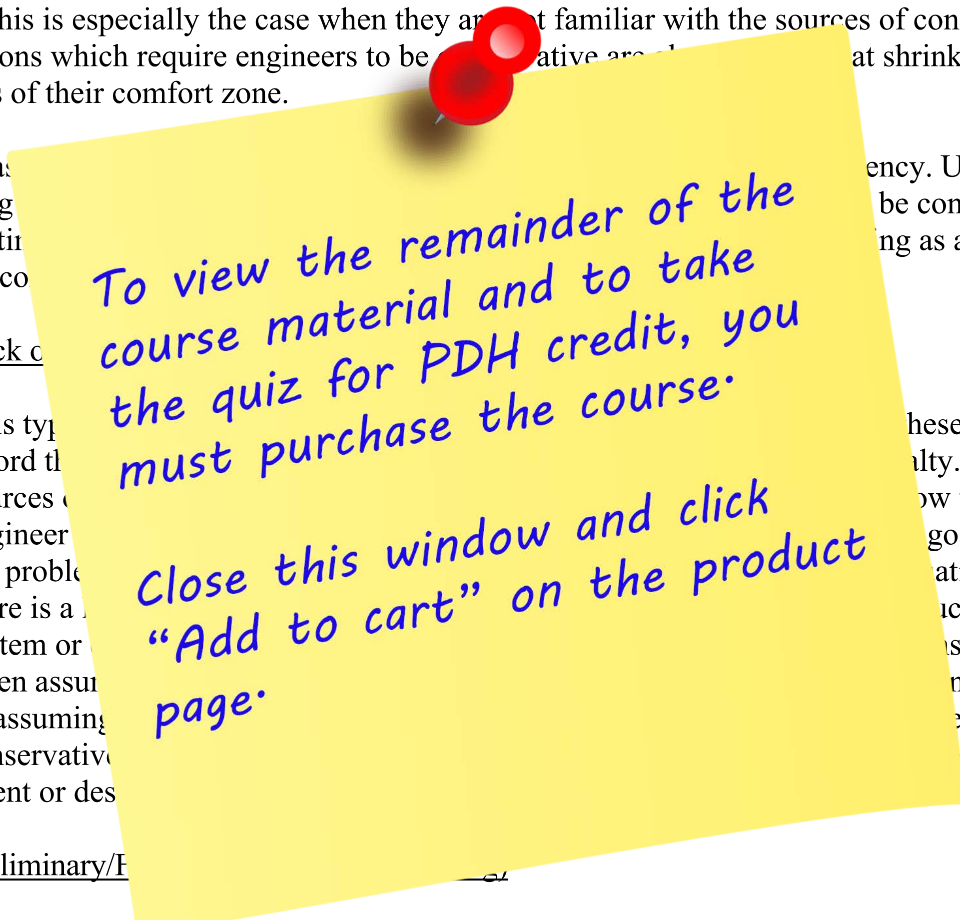
Required Load = 1.5 x 20 Tons = 30 Tons, Therefore a 3.25" Pin Shackle should be selected, however the shackle now has an equivalent safety factor of 1.5 x 2.75 = 4.125

Alternatively, the table should be entered with the base 20 Ton load and shackle size determined from that value. Actually, a 2.5" Pin Shackle can be used with a higher safety factor than required.

2.0 Knowing "How" and "When" to be Conservative

Knowing "When" to be Conservative

As long as engineering exists, there will always be a need to be conservative. In order to recognize "when" to be conservative it must be understood what are the key sources of conservatism. The sources are almost always engineering assumptions and general practice as it relates to engineering preference. There are numerous situations that arise which require engineers to be conservative. For the seasoned engineer these situations become apparent and obvious. However, for the not so experienced engineer situations like these could leave one puzzled. This is especially the case when they ar t familiar with the sources of conservatism. The situations which require engineers to be c ative are al at shrink the boundaries of their comfort zone.



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Preliminary/F

When preparing preliminary or front-end deliverables, all of the intricate details of the final deliverable are usually not required. Factors such as estimated cost, constructability, and conceptual interpretation are held paramount. This is where conservatism is appreciated as well as encouraged. It is encouraged at this phase because when a conceptual design is presented and approved it is easier, and more favorable to shave off conservatism as the deliverables progress toward completion. This translates to cost reduction instead of cost increases or other costs that could arise due to changes.