Using AI Chatbots to Produce Engineering Spreadsheets in an Advanced Structural Steel Design Course

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Abstract

Engineers have historically embraced the use of technology to increase efficiency, reduce errors in calculations, and produce high quality projects on a shorter timeline. The Excel spreadsheet is a prime example of how engineers embraced technology for those reasons. Excel has been a staple in producing an immeasurable number of engineering calculations. However, humans have always been responsible for spreadsheet development and, unfortunately, humans will inherently produce errors within spreadsheets. But what if an engineer can reduce the number of errors and produce a spreadsheet in less time by utilizing artificial intelligence (AI)?

This paper will discuss incorporating the use of AI Chatbots, such as ChatGPT, Claude 3, and Gemini (formerly known as Bard), into an advanced steel design course. The course is centered around a semester long project where Architectural Engineering students design and analyze a multi-story steel structure. Students throughout the semester will use an AI Chatbot to create spreadsheets by asking it to develop Visual Basic for Applications (VBA) code that can then be inserted into Excel spreadsheets. The resulting spreadsheet will be compared to hand-calculations and RISA output to determine the accuracy of the VBA code and error reduction produced by AI Chatbots.

Introduction

It is a common belief that engineers love their spreadsheets and there is a lot of truth in that statement since most engineers use at least one form of software to aid in their design and analysis process. Technological advancements have certainly allowed engineers to increase their efficiency, reduce errors in their calculations, and produce projects on a shorter timeline. With the media increasing its focus on the beneficial uses of artificial intelligence (AI) in various fields of study and professional disciplines, there is a need to understand if this technology can be used by structural engineers and whether Architectural Engineering students should be introduced to this technology during their academic career.

There is current literature devoted to understanding the role of AI specifically within the field of structural engineering. Lagaros and Plevris [1] state, "AI methodologies have found a wide range of uses and applications in engineering field, including civil and structural engineering, with impressive results." Additionally, Huu-Tai Thai [2] provides a compressive review regarding machine learning for structural engineering that includes a large number of applications where AI is already being used in the structural engineering profession. While these references do list practical uses for AI within the field of structural engineering, it is apparent that a background in this technology would be required to develop or even use some of the engineering applications that are discussed. The reality is that most structural engineers and engineering students do not have formal training in coding or software development. Therefore, there does not appear to be a clear path on how AI can be quickly adopted for the general use of a structural engineer or engineering student. For this reason, we seek to discover if the use of AI Chatbots could potentially be used as a gateway for the use of AI in structural engineering.

An AI Chatbot is a computer program that simulates human conversation with an end user [3].

Although not all Chatbots use AI, this paper will consider Chatbots that are equipped with conversational AI techniques that allow them to understand the user's questions and automate responses to them. There are many free versions of AI Chatbots available to the public and using these programs are incredibly user friendly.

By leveraging the popularity of Excel in the development of spreadsheets to produce engineering calculations and the ease of use of AI Chatbots, we have introduced AI Chatbots within an advanced structural steel design course at Oklahoma State University to determine if the use of AI Chatbots can help reduce the number of errors in spreadsheet development and produce spreadsheets in less time than without the use of AI Chatbots.

Importance of Introducing AI Chatbots to Students

Although artificial intelligence has been around for decades, media attention on artificial intelligence and specifically AI Chatbots has significantly increased since OpenAI released an early demo of ChatGPT on November 30, 2022 [4]. In fact, ChatGPT is the fastest-adopted tool in the Internet age based on the time it took for selected online services to reach 100 million users, surpassing TikTok, Instagram, Facebook, and Netflix to name a few [5]. To further put this into perspective, ChatGPT reached over one million users in five days and over 100 million users within 2 months, compared to Spotify which took 11 years to reach 100 million users [4, 5].

The combination of increased media attention and the capability of this powerful resource presents a challenge within academia. Instructors are placed in a position where they need to address whether students should be allowed to utilize artificial intelligence to assist in completing coursework. There are strong arguments on both sides of this debate. Some believe that the use of artificial intelligence to complete coursework is an academic integrity violation and should not be used, while others believe artificial intelligence can be used ethically and within academic integrity standards to be a resource for students. And of course, there are academics that stand somewhere in between. The lack of clarity on the use of AI in the classroom and the disjointed opinions among professors, even within the same college or university, has led to confusion among students on whether ChatGPT is taboo or a powerful tool. To try and understand whether students that are majoring in Architectural Engineering should be introduced to AI Chatbots, a search into what the structural engineering industry is trending towards was conducted.

It is apparent that organizations within the structural engineering community are in the process of trying to educate structural engineers on the practical uses of artificial intelligence. A joint initiative between the National Council of Structural Engineers Associations (NCSEA), the National Institute of Building Sciences (NIBS), and Oregon State University established Artificial Intelligence in the Structural Engineering Profession as the topic for the 2023-2024 Innovation in Structural Engineering Grant. Additionally, the American Institute of Steel Construction (AISC) awarded the 2024 AISC Milek Fellowship award to Mohannad Z. Naser, an Assistant Professor at the Clemson University School of Civil and Environmental Engineering and Earth Sciences, for his research proposal "SteelGPT: Automating Structural Design of Steel Structures." His research aims to use artificial intelligence and machine learning to create a virtual assistant named SteelGPT that will help enhance the steel design process.

Research also suggests that professionals are already using ChatGPT with 43% of employees stating they have used ChatGPT in their work, while 68% of those users have not told their bosses they are doing so [5]. Based on these findings and the understanding that the structural engineering community is currently investing resources to identify how artificial intelligence will play a role in the profession, it was decided that we should provide our students with at least an introduction to AI.

Advanced Structural Steel Design Course Overview

The advanced structural steel design course (Steel II) is typically taken by Architectural Engineering (ArchE) students at Oklahoma State University during the spring semester of their third year. In recent years, this class was used to introduce building information modeling (BIM) to students in order to prepare them for professional practice [6]. So, it seemed to be a natural fit to also utilize this course as a way to introduce students to artificial intelligence and specifically how AI Chatbots could be used within the structural engineering profession.

The Steel II course is the second required steel design course in an ArchE student's curriculum and is a follow-up to the introductory structural steel design course (Steel I) that is typically taken during the fall semester of their third year. As a prerequisite to Steel II, students have also successfully completed a Structural Loadings course that introduces students to both gravity and lateral loads required by both the International Building Code (IBC) and Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-22). This is important to note because historically gravity and lateral loads were introduced to students during this course. If that were still the case, we would not have enough time in the course to introduce new technological advances. Additionally, it is important to note that the course is currently structured with three hours of lecture and a one-hour lab component. Students are introduced to structural components, design, analysis, and detailing of structural systems during lecture periods, but they are also provided lab time in which students focus primarily on a semester long project. It is this project where we have included the incorporation of AI Chatbots into the course.

The project varies in building layout and location each semester, but for the 2024 spring semester students were tasked with providing the structural analysis, design, and detailing of a three-story steel structure located in Oklahoma City, Oklahoma. As a part of their project assignments, students develop a professionally formatted project manual detailing the code required loads and present their calculations for the analysis and design of steel deck, composite and non-composite slabs, beams, light-weight steel joists, columns, bracing, and connections to meet steel specification criteria for strength, stiffness, and stability. Students submit bi-weekly assignments that build upon one another to create the project manual and at the end of the semester create construction documents that include general notes, typical steel details, framing plans, framing elevations, and enlarged details.

In past semesters, students relied on a combination of hand calculations and the structural analysis software RISA to analyze and design the structural components of the building. However, students are now tasked with the addition of using AI Chatbots to generate Visual Basic for Applications (VBA) code. This code will be run by macros within Microsoft Excel to create an engineering spreadsheet that can be used to verify hand calculations and RISA output for the steel structure.

The students do not currently have a class where VBA code is taught. Their current programming

course is primarily focused on Python as a coding language, but it was decided to use VBA for this semester so that students are less likely to manually manipulate the code generated by the AI Chatbots since they are unfamiliar with the VBA coding language. Also, Excel is a common software used by structural engineers in the industry to create spreadsheets and VBA has historically been the preferred code used to automate tasks in Excel. It is understood that Excel will be incorporating Python within the software, but the current version available to students at Oklahoma State University does not currently include this capability.

Introduction of AI Chatbots to the Course

In order to have students buy into the idea of using AI Chatbots in the course and to invoke excitement among the students, the use of AI Chatbots was used extensively in making revisions to the current course structure and development of new assignments. Proper references are made in the course materials to show what has been generated by AI Chatbots. This helps provide students with examples of properly citing AI Chatbots and demonstrate the importance of citing it as a reference.

ChatGPT was also used to develop a course image used in the web-based learning management system Canvas. The image was generated by DALL-E, which is an image generation tool that uses text prompts from ChatGPT 4. DALL-E was also used for each lecture to generate an image that is placed on the cover slide of the course lecture. The idea of incorporating these images is to spark interest in the students since the images usually try to involve a comical twist on what they will be learning during that lecture. Figure 1 shows the cover slide for the first lecture discussing composite beams. To generate the image in Figure 1, the text prompt into ChatGPT 4 was, "create a comical image that appears to tell a love story between a structural steel beam and a concrete beam."

Figure 1: Cover slide for composite beam design with DALL-E generated image

ChatGPT was also used to revise the project overview to create a scenario that makes the project feel more like a real-world structural engineering project. Figure 2 shows the project overview that was provided to students in the spring 2023 semester. Although this overview provides students with the necessary information to complete the project, it does not successfully engage the students in the

project. Figure 3 shows the revised project overview that was provided to students in the spring 2024 semester. The revised project overview was mainly generated by ChatGPT 4 where the text from the spring 2023 overview was input as a user prompt and ChatGPT was asked to revise the overview for a more realistic project scenario. There were a few manual changes made, but the overall layout and scenario was largely generated by ChatGPT in less than one minute. By setting the stage with AI generated content produced by their professor on the first day of class, students appeared to be invested and ready to learn how to use AI Chatbots on their own.

PROJECT **ARCH3343** **SPRING 2023**

Topic: **Multi-story Steel Design Project**

This semester will consist of working on a single project throughout the entire semester. Each student will be responsible for completing all the work necessary to design and detail a multi-story steel structure for the following conditions. Assignments that build towards the final result will be assigned throughout the semester. It is the goal of this project to give the student the experience of designing and documenting a multi-story steel structure:

Building:	Three story office building for 750 workers
Location:	2015 Grand Blvd. Kansas City, MO 64108
Building Code:	2021 International Building Code
Structure:	Moment frame / braced frame in opposite directions
Facade:	TBD w / lightgage metal framing, and Glass Curtainwall
Floor Heights:	As shown on elevation
Parapet:	Typically 3'-6" above top of roof deck
Fire Protection:	2-hour rating, sprinkled
Foundation:	Limestone bearing stratum at 15'-0" below ground floor elevation exists with layers of clayey soils lying above the limestone. Perimeter of building to be supported on grade beams. Allowable end bearing pressure for bearing stratum is 30 ksf and skin friction is 4.0 ksf for portion into bearing stratum, after initial 2' penetration.
Design Codes:	**ASCE/SEI 7-22**: *Minimum Design Loads for Buildings and Other Structures* **AISC** Steel Construction Manual – 15th edition

Figure 2: Project Overview from Spring 2023

PROJECT **ARCH3343** **SPRING 2024**

Steel Structure Office Building in Oklahoma City

Background

A leading architecture firm, Skyline Design Group (SDG), has been commissioned to design a state-of-the-art office building in downtown Oklahoma City. SDG has hired your structural engineering firm to provide the structural design and analysis for the project. The project aims to create a sustainable, safe, and aesthetically pleasing workspace for approximately 750 employees of a prominent tech company.

Client

Name: Nexus Tech Inc.

Industry: Artificial Intelligence

Requirements: Since the client specializes in the development of artificial intelligence, they are requesting that artificial intelligence be incorporated into the design and analysis of the structural design of the building.

Project

Name: TechHaven Tower

Building Codes:

- 2021 International Building Code (IBC 2021)
- ASCE/SEI 7-22: Minimum Design Loads for Buildings and Other Structures
- AISC Steel Construction Manual – 15th Edition

Structure: Use of steel moment frames and braced frames

Façade: To be determined

Fire Protection: 2-hour rating, fully sprinkled

Foundation per Geotechnical Report: Limestone bearing stratum at 15'-0" below ground floor elevation exists with layers of clayey soils lying above the limestone. Perimeter of building to be supported on grade beams. Allowable end bearing pressure for bearing stratum is 30 ksf and skin friction is 4.0 ksf for portion into bearing stratum, after initial 2 feet of penetration.

Location

Address: 100 Tech Parkway, Oklahoma City, OK 73102

Site Characteristics: Urban setting with close proximity to public transportation and city amenities. The site is currently a vacant parking lot located at the corner of Thunder Drive and Reno Avenue.

Outcome

Upon completion, TechHaven Tower will serve as a model for modern office design, fostering a collaborative and productive environment for Nexus Tech's workforce while enhancing the architectural landscape of Oklahoma City. The project will also highlight how artificial intelligence can be used by the structural engineering community for the design and analysis of structures.

Note: The project scenario was created by ChatGPT 4 with input and revisions from Professor Campbell.

Figure 3: Project Overview from Spring 2024

Now that students were invested in using AI Chatbots, a lecture period was devoted to an AI Chatbot introduction which discussed how to leverage AI tools responsibly, how to cite AI Chatbots, demonstrations on the interfaces of ChatGPT, Claude 3, and Gemini, as well as the key differences between these three popular AI Chatbots. Students were also introduced to VBA, macros, and the developer tabs within Microsoft Excel. Next, students were provided with an example on how to use ChatGPT to create a plot of the bending moment diagram for a uniformly loaded, simply supported beam. The purpose of the exercise was not only an introduction on using ChatGPT and Excel, but also so that any issues that were encountered by the students could be promptly addressed by the instructor in order to try and prevent frustration by the students in performing the activity for the first time.

However, there were a few common errors that were encountered. For example, ChatGPT typically provided the plot of the bending moment graph using metric units. Students were told to prompt ChatGPT to revise the code using imperial units with kips and feet. Another common error was when students tried to run the macro in Excel they were presented with an error running the code in Excel. The students were instructed to copy and paste the error message into ChatGPT and prompt it to revise the code to resolve the error. The third major issue was in the way that the VBA code was written by ChatGPT and how it referenced the cells to be included in the graph of the moment diagram. ChatGPT would consistently plot both the moment as a series and the location along the longitudinal axis of the beam as a series (Figure 4).

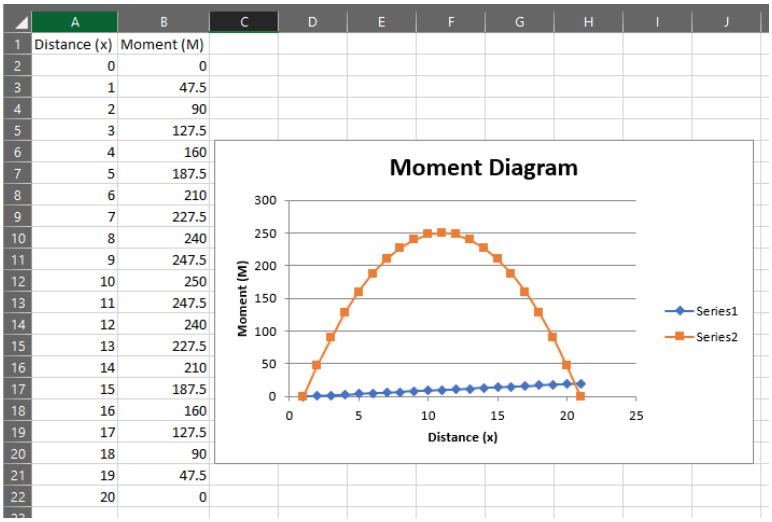


Figure 4: Excel Output with Incorrect Moment Diagram

One issue that was observed during this exercise was when students tried to ask ChatGPT to complete too many steps within one prompt or they tried to move on to the next step in the example without resolving issues in the step before it. In these cases, students received incorrect information or code that lacked key pieces of information. This created some frustration and it appeared to show lack of confidence in the abilities of the AI Chatbot. A discussion that focused on how the output is only as good as the user prompts took place and strategies for improving user prompts was also discussed. Students discovered that they needed to be direct with the AI Chatbot and provide methodical prompts that walked the AI Chatbot through the process. If this example is used in the future, a flow chart of prompts prior to starting the exercise may be helpful for students to identify the

key pieces of information required. It is also recommended to start the exercise with the prompt, "what is the equation for a simple beam with uniform load?" instead of the current prompt of jumping straight to "provide VBA code that graphs the moment diagram of a simple beam with uniform load." This will ensure that the AI Chatbot is using the correct equation prior to starting and if it isn't, the user can prompt the Chatbot with the correct equation and state for it to use the corrected equation moving forward.

The last exercise used to fully introduce AI Chatbot into the course was for students to use it in conducting research on exterior façade systems. As a part of the first project assignment, students were tasked with researching an exterior wall system and providing a summary of the exterior wall system including advantages and disadvantages, a sketch of the exterior wall system highlighting each component of the exterior wall, a breakdown of façade dead loads, and their AI Chatbot prompts and responses. Based on their research, the students selected a façade system to use on their project. The purpose of this assignment is to provide an introduction on how AI Chatbots can be ethically used as a research tool and how to properly cite generative AI tools. It was also discovered by a student that Gemini seemed to handle this task better than ChatGPT, possibly due to the suspicion that Gemini can access the internet in producing its responses.

Discussion on AI Assignments and their Results

There are a total of five assignments that utilize AI Chatbots to create engineering spreadsheets throughout the semester and students have approximately two weeks to complete each assignment along with their project submissions. Each of these assignments have been included in Appendix 1. The assignments are coordinated so that they are relevant to both the lecture material and where the students are in the project design process.

The first AI assignment is a continuation of the in-class example where students were creating a plot of the moment diagram of a simple beam with uniform load. However, this assignment also required the students to graph the shear diagram, and deflection of the same beam. The purpose of this assignment is to engage students and have them determine the accuracy of what the AI Chatbots are providing them. By using shear, moment, and deflection diagrams of a simple beam with uniform load, it is anticipated that students are familiar with what the expected results should be and can easily identify errors if present.

In the first assignment, there were many lessons learned that could potentially be corrected in future revisions of the course. Although the instructor of the course and the teaching assistant completed the example prior to the start of the class with no issues, when the students began the exercise, they all received varying incorrect solutions and ChatGPT stubbornly refused to fix some of the issues despite their pleas to revise them. After the reports of ChatGPT not performing as intended, the instructor tried to repeat the exercise and could not get the results that were previously produced. This unveiled the first major challenge with using AI Chatbots. For the time being, AI Chatbots are black-boxes. We are not able to see behind the curtain to understand their proprietary training methods and we are reliant on what the AI Chatbots have learned from their training.

The second lesson learned from this assignment is that there is a significant difference in the responses received from the free version ChatGPT 3.5 and the paid version ChatGPT 4. When

prompted "what is the moment equation of a simple beam with a uniform load?" ChatGPT 3.5 would almost always provide incorrect equations and the equations would be different each time it was asked. However, when the same prompt was presented to ChatGPT 4, the correct moment equation was provided more often. Claude 2 (now known as Claude 3) was also used with varying levels of success. After about a week of trying to manipulate prompts within ChatGPT to duplicate the successful results that occurred prior to the start of the semester, the instructor was finally able to produce a correct moment diagram.

The issues presented in the first assignment sparked an investigation into why the AI Chatbot would work flawlessly for some time and then seemingly stop working. Although this may not be the primary reason, it was discovered that other users were having similar issues with ChatGPT and specifically with having it produce code. Many news outlets reported what is now known as the ChatGPT Winter Hypothesis, which is essentially that the reduced number of users during the winter months of 2023 into 2024 had made ChatGPT lazy and some even stating that it was suffering from seasonal depression [7]. The widespread complaints caused OpenAI to investigate the issue with their Chatbot and even releasing the following statement, "we've heard all your feedback about GPT4 getting lazier! We haven't updated the model since Nov 11th, and this certainly isn't intentional. Model behavior can be unpredictable, and we're looking into fixing it" [7].

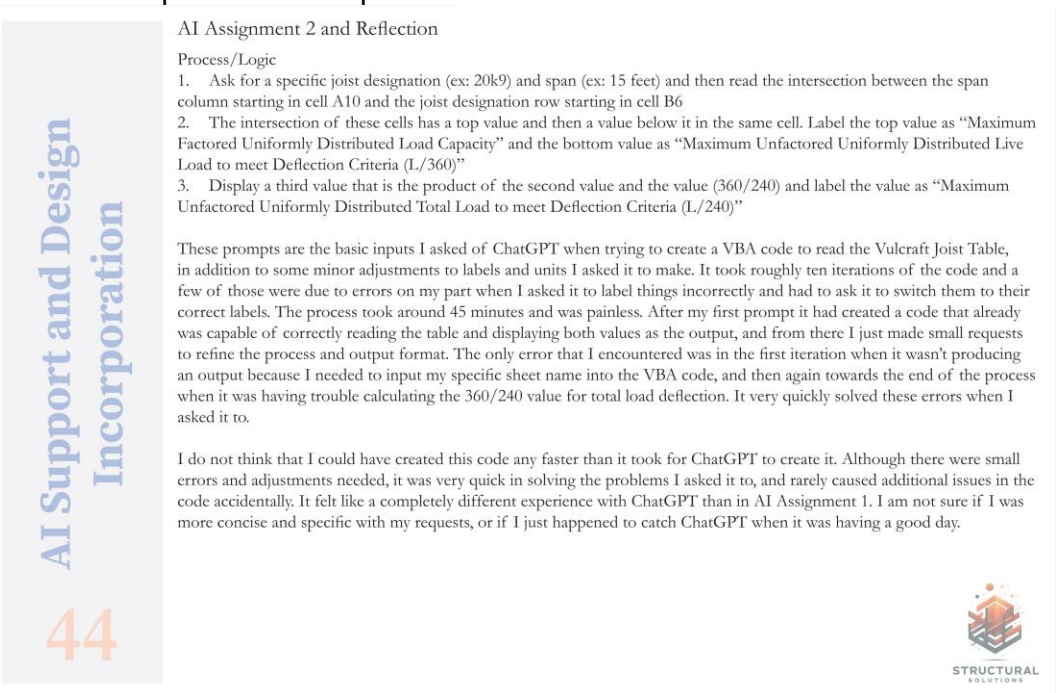
Due to the issues encountered with the first exercise, students did not complete the assignment and were instead asked to focus their attention on writing a reflection on why AI Chatbots may not be ready to produce graphs within Excel at this time. Students also reflected on the issues they encountered when trying to complete the assignment and if they felt they could have accomplished the task in Excel faster and more accurately without the assistance of the AI Chatbot. The feedback received overwhelmingly suggested that AI Chatbots are not ready to produce VBA code the generates graphs within Excel for the time being and creating these graphs manually may be a better option since it would be faster and result in less errors.

AI Assignment 2 focused on using AI Chatbots to develop VBA code that would pull information from an Excel database that contains the Vulcraft LRFD Joist catalog. This assignment is intended to use Excel for one of its primary strengths, using databases and pulling key pieces of information from it. In this assignment, students were tasked with creating VBA code that would output the maximum total factored uniformly distributed load capacity for a specific joist designation and span. The code would also need to provide the maximum total unfactored uniformly distributed load to meet deflection criteria (L/240) for a specific joist designation and span. Lastly, the code would need to provide the maximum uniformly distributed live load to meet the deflection criteria (L/360) for a specific joist designation and span. The main purpose of this assignment is to present new challenges to the students and develop their skills on how to communicate with AI Chatbots. It was intentional to provide something that can be easily determined by looking at the Vulcraft catalog or by using the features found on Vulcraft's website for students to be able to check the accuracy of the output provided by the AI Chatbot. This assignment is also a precursor to helping students complete AI Assignment 3.

Additionally in AI Assignment 2, more instruction was provided to the students to include their process and logic. The thought behind this was that students would take some time prior to

starting their discussion with the AI Chatbot and have more understanding of what they are trying to accomplish and how they can work toward achieving this goal.

Based on student reflections, it appears the students who followed the instructions to create a flow chart of their process and logic tended to have a better experience in completing this assignment. Figure 5 is an example of a student's reflection from this assignment and Figure 6 is an example of another student's flow chart. However, there were still difficulties in completing the assignment for most students. One of the main issues involved having the maximum total unfactored uniformly distributed load and the maximum uniformly distributed live load both located in a single cell with a line break used to divide the values. For some students, the AI Chatbot could not separate and interpret these values as individual values.


AI Support and Design Incorporation

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AI Assignment 2 and Reflection

Process/Logic

1. Ask for a specific joist designation (ex: 20k9) and span (ex: 15 feet) and then read the intersection between the span column starting in cell A10 and the joist designation row starting in cell B6
2. The intersection of these cells has a top value and then a value below it in the same cell. Label the top value as "Maximum Factored Uniformly Distributed Load Capacity" and the bottom value as "Maximum Unfactored Uniformly Distributed Live Load to meet Deflection Criteria (L/360)"
3. Display a third value that is the product of the second value and the value (360/240) and label the value as "Maximum Unfactored Uniformly Distributed Total Load to meet Deflection Criteria (L/240)"

These prompts are the basic inputs I asked of ChatGPT when trying to create a VBA code to read the Vulcraft Joist Table, in addition to some minor adjustments to labels and units I asked it to make. It took roughly ten iterations of the code and a few of those were due to errors on my part when I asked it to label things incorrectly and had to ask it to switch them to their correct labels. The process took around 45 minutes and was painless. After my first prompt it had created a code that already was capable of correctly reading the table and displaying both values as the output, and from there I just made small requests to refine the process and output format. The only error that I encountered was in the first iteration when it wasn't producing an output because I needed to input my specific sheet name into the VBA code, and then again towards the end of the process when it was having trouble calculating the 360/240 value for total load deflection. It very quickly solved these errors when I asked it to.

I do not think that I could have created this code any faster than it took for ChatGPT to create it. Although there were small errors and adjustments needed, it was very quick in solving the problems I asked it to, and rarely caused additional issues in the code accidentally. It felt like a completely different experience with ChatGPT than in AI Assignment 1. I am not sure if I was more concise and specific with my requests, or if I just happened to catch ChatGPT when it was having a good day.

STRUCTURAL SOLUTIONS

Figure 5: Student Reflection for AI Assignment 2

For AI Assignment 3 students were asked to create VBA code that would allow a user to enter a specified uniform dead and live load to solve for a joist designation that can safely support the uniform load. The code needs to search the Vulcraft joist excel database and list all acceptable joist designations, list the joist designation with the least weight, and the joist with the shallowest depth that can safely support the factored load on a professionally formatted sheet titled "Output." This assignment was designed to provide an example of a spreadsheet that could be useful for the practicing engineer.

Unfortunately, only a handful of students completed this assignment. It is believed that at this point in the semester students had difficulty completing the project assignment and the AI assignment in unison and decidedly spent more attention on the project assignment which had a higher weighted average on their grade. Additionally, since this built upon AI Assignment 2, those students who did not complete the previous assignment could not complete this assignment easily although the instructor did provide their version of AI Assignment 2 to the class. In future iterations of the course, having assignments that build on each other is not recommended.

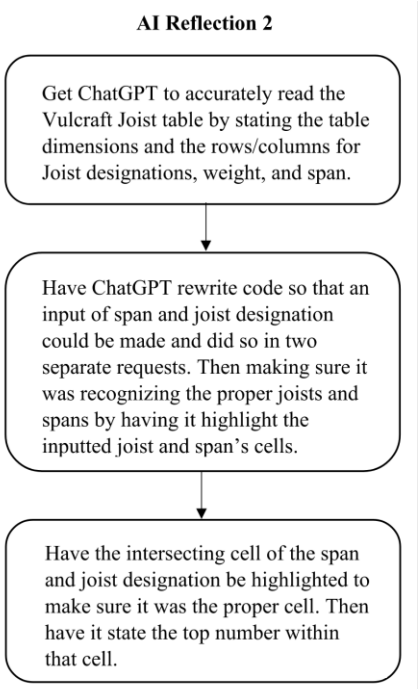

Figure 6: Student Flow Chart of Logic for AI Assignment 2

AI Assignment 4 moved on to dealing with the design of fully composite beams. This assignment only dealt with fully composite beams to allow students to focus more on how to utilize AI Chatbot for this assignment. It also allowed students to quickly check their work and anticipate reasonable results so that errors could be caught. This assignment had students utilize an Excel database that is essentially AISC Table 3-19, which is a reference for the available strength in flexure of composite W-shapes. This assignment also tested a new possibility in spreadsheet development. Instead of having the students use an AI Chatbot to develop VBA code to create whole spreadsheets, the students are tasked with developing a spreadsheet in the more traditional sense of inputting values into cells and setting up their sheets. The AI Chatbot was only used to assist in creating formulas that the user is not familiar with how to accomplish or VBA code for the more complex tasks.

Due to difficulties and low participation from students in completing the previous assignments, it was decided that the instructor and the TA would spend a lecture period demonstrating their own conversations with an AI Chatbot and complete demonstrations of what the desired result of AI Assignment 4 and 5 was. Students were asked to only write a reflections on the lecture and demonstrations.

By performing the demonstrations, it appeared to have success in not only increasing student participation (went from 5 students completing AI Assignment 3 to 14 students completing AI Assignment 4), but also allowed students to better understand prompt engineering. Prompt engineering is crafting input prompts in specific ways to guide the AI model's responses. One student stated in their reflection, "After Professor Campbell explained his logic, it appeared that I had been thinking about the AI assignments wrong."

It is interesting to note that even though the students witnessed the successful completion of an assignment using an AI Chatbot, the majority of students still wrote in their reflections that they did not see the benefit to using the AI Chatbot and that they might have been able to develop the spreadsheet faster without the use of AI Chatbots. These comments warranted further investigation into why students felt AI Chatbots were not efficient at developing engineering spreadsheets.

It is believed that most of the students have a misconception that AI provides immediate solutions. Additionally, at this point in the students' academic career, they do not have experience developing significant spreadsheets for engineering calculations, and they suspect that spreadsheet development should occur quickly. Students wrote in reflections that they spent approximately 30 minutes on the assignments before giving up, when the instructor had estimated approximately 2 hours to complete the assignment. The disconnection between the students' understanding of the time commitment and a better understanding of time required to develop significant engineering spreadsheets in the industry needs to be addressed in future iterations of the course.

AI Assignment 5 built on AI Assignment 4 where students were told that the design of the fully composite beam is deemed too conservative, and they need to find a partially composite beam with the least number of headed studs that can safely support the required load based on flexural strength. As previously discussed, it is not advised to have these AI assignments built on each other if students are completing the work. However, for this assignment the course's teaching assistant provided a demonstration of interactions with the AI Chatbot and completion of the assignment and students were asked to write a reflection on the demonstration. The students' reflections were like their remarks from AI Assignment 4 in that they did not see a real benefit to using AI Chatbots in their spreadsheet development.

Conclusions

The use of AI Chatbots is potentially a promising gateway to introducing structural engineers and engineering students to the capabilities of artificial intelligence. While there are demonstrated weaknesses in current versions of AI Chatbots, it is hopeful that they will continue to improve rapidly over time. For now, AI Chatbots may be better utilized as a research tool, as demonstrated in the exterior wall research performed by the students, or to help write draft emails or proposals. However, understanding the capabilities of AI Chatbots does appear to allow more experienced users to successfully generate spreadsheets for the use of engineering calculations more efficiently than creating them manually, but the number of errors are not necessarily reduced.

For students who are relatively inexperienced at spreadsheet development and are learning new material, the use of AI Chatbots does not allow for spreadsheet development to occur more efficiently or with a reduction in the number of errors. In fact, it was demonstrated through 5 assignments utilizing AI Chatbots that students are less likely to complete the development of spreadsheets if they are required to use AI Chatbots to assist them. However, due to the increasing call from engineering organizations and structural engineering firms to discover how AI can be incorporated into structural engineering, it is imperative that we still seek to unfold

how AI can be used and it is essential that as educators we introduce this technology to our students.

Additionally, it was observed that most students used ChatGPT to complete their assignments rather than exploring alternative AI Chatbots such as Claude 3, Gemini, or Pi. This is likely due to the popularity and media attention of this AI Chatbot, but based on the instructor's experience, ChatGPT may not be the best option for certain tasks. An investigation into which AI Chatbot is a better assistant in completing spreadsheet development for engineering calculations should be further investigated.

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Appendix 1

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AI Assignment #1

Due as a part of your Project Submission 1

By utilizing AI Chatbots, create VBA code to solve for the moment, shear, and deflection of a simply supported uniformly loaded beam. The code should also create individual graphs with the moment, shear, and deflection plotted.

Write a reflection on this assignment. In the reflection include at a minimum the following:

1. Advantages and disadvantages to using an AI Chatbot to develop these graphs.
2. Did you encounter any errors produced by the Chatbot? How did you detect these errors and how did you resolve them?
3. Total time spent completing the assignment. Do you feel you could have accomplished this task in excel faster without AI assistance?

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AI Assignment #2

Due as a part of your Project Submission 2

By utilizing AI Chatbots and the provided Vulcraft LRFD Joist catalog excel document, create VBA code that accomplishes the following:

1. Provides the maximum total factored uniformly distributed load capacity for a specific joist designation and span.
2. Provides the maximum total unfactored uniformly distributed load to meet deflection criteria (L/240) for a specific joist designation and span.
3. Provides the maximum uniformly distributed live load to meet the deflection criteria (L/360) for a specific joist designation and span.

Consider the following during this assignment:

1. What if you enter a joist designation that does not exist?
2. What if you enter a span that does not have a value in the table for that specific joist designation?
3. How can you manage having two lines of text that are stacked on each other (i.e. the black figure and red figure for loads)?

Write a reflection on this assignment. In the reflection include at a minimum the following:

1. Your initial set-up, logic, and/or flowchart and strategy for accomplishing this task.
2. Did you attempt to layer your Chatbot requests (i.e. did you use a single conversation or multiple)?
3. Did you encounter any errors produced by the Chatbot? How did you detect these errors and how did you resolve them?
4. Total time spent completing the assignment. Do you feel you could have accomplished this task in excel faster without AI assistance?

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AI Assignment #3

Due as a part of your Project Submission 3

By utilizing AI Chatbots, the previously provided Vulcraft LRFD Joist catalog excel document, and previous AI assignments create VBA code that accomplishes the following:

1. Allows you to enter a specified uniform dead and live load to solve for a joist designation that can safely support the uniform load.
2. Title a sheet in the excel document “Output” and include output that provides all acceptable joist designations, output that provides the least weight joist designation, output that provides the shallowest depth joist designation, and output that provides a joist designation with the least weight and shallowest depth. Make sure the output is organized and professionally presented on the sheet.

Consider the following during this assignment:

1. If you want to start a new calculation, what happens to the old information?

Write a reflection on this assignment. In the reflection include at a minimum the following:

1. Your initial set-up, logic, and/or flowchart and strategy for accomplishing this task.
2. What were the main challenges of this assignment and how did you overcome them?
3. Did you encounter any errors produced by the Chatbot? How did you detect these errors and how did you resolve them?
4. Total time spent completing the assignment. Do you feel you could have accomplished this task in excel faster without AI assistance?

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AI Assignment #4

Due as a part of your Project Submission 4

By utilizing AI Chatbots, AISC Table 3-19 and the select beam from our project, create VBA code that accomplishes the following:

1. Determines the beam size with the least weight that will safely support the required load based on flexural strength. Assume fully composite beam, a= 2”, and beam is shored until concrete is hardened.
2. Determines the flexural capacity (ΦM_n) of the selected beam size.
3. Determines the total number of headed studs required.

Consider the following during this assignment:

1. Manual intervention may be required in this assignment.

Write a reflection on this assignment. In the reflection include at a minimum the following:

1. Your initial set-up, logic, and/or flowchart and strategy for accomplishing this task.
2. What information is the AI Chatbot able to provide? Did you need to provide any manual interventions in order for it to complete the tasks successfully? If so, state what modifications you made.
3. Did you encounter any errors produced by the Chatbot? How did you detect these errors and how did you resolve them?
4. Total time spent completing the assignment. Do you feel you could have accomplished this task in excel faster without AI assistance?

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AI Assignment #5

Due as a part of your Project Submission 5

The fully composite beam design from AI Assignment 4 was determined to be too conservative. By utilizing AI Chatbots, AISC Table 3-19 and your previous AI Assignments, create VBA code that revises your AI Assignment 4 to find the least number of headed studs required to safely support the required load based on flexural strength.

Write a reflection on this assignment. In the reflection include at a minimum the following:

1. Your initial set-up, logic, and/or flowchart and strategy for accomplishing this task.
2. What information is the AI Chatbot able to provide? Did you need to provide any manual interventions in order for it to complete the tasks successfully? If so, state what modifications you made.
3. Did you encounter any errors produced by the Chatbot? How did you detect these errors and how did you resolve them?
4. Total time spent completing the assignment. Do you feel you could have accomplished this task in excel faster without AI assistance?