

Transforming Structural Engineering: Examining the Opportunities and Risks of ChatGPT and Other Large Language Models

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Abstract

The advancements in technology, particularly the development of high-performance computing (HPC) and large language models (LLMs) like ChatGPT, can potentially transform the field of Structural Engineering. Use of LLMs, such as ChatGPT, offers several opportunities in Structural Engineering, including the development of innovative design solutions, use in code-based structural analysis programs by automating repetitive coding tasks, conforming to building code requirements by automating compliance checks, and storing information. The critical concerns arise in LLM's regarding biases, misinformation, safety, reliability, and lack of domain expertise. This paper explores the opportunities and risks associated with using ChatGPT and LLMs in Structural Engineering, focusing on efficiency, accuracy, and reliability. The main aim of the study is to examine the limitations and potential risks of relying solely on machine-generated information and to provide mitigation strategies to overcome them. Careful management to prevent harmful content, collaboration with human experts for accurate results, establishing guidelines and standards are obligatory measures to address ethical concerns such as bias, privacy, and abuse. Continuous monitoring and updating of LLMs are essential to maintain accuracy and relevance. While ChatGPT and LLMs offer significant benefits in Structural Engineering, responsible usage in combination with human expertise and machine-generated insights are vital to maximizing their potential while mitigating risks and ensuring safe as well as reliable engineering practices.

Keywords: ChatGPT, Structural Engineering, Large Language Models, Automation

1. Introduction

Structural Engineering is a field transformed by technological advances, including the development of high-performance computing (HPC) and, more recently, large language models (LLMs) like ChatGPT. HPC has enabled engineers to optimize large structures subjected to the complicated, implicit, and discontinuous constraints of commonly used design codes and regulations (Adeli and Soegiarso, 1998). With the development of computational and construction techniques, structural optimization has become increasingly popular and been applied to larger and more complex structures (Mei and Wang, 2021).

LLMs such as ChatGPT and Perplexity have the potential to transform the way structural engineers approach the design and analysis of buildings and infrastructure. By processing vast amounts of data and providing insights in real-time, an AI-powered tool can help engineers make more informed decisions about materials, design configurations, and innovative design solutions that help in simulation of seismic data (Yoshimura, Hori and Ohsaki, 2016). Use of ChatGPT in the field of construction planning, software engineering and overall civil engineering aspects have been discussed in previous studies (Qadir, 2023, Prieto, Mengiste and García de Soto, 2023, Choudhury and Shamszare, 2023, Aluga, 2023). This paper aims to examine the opportunities and risks of using ChatGPT and LLMs in Structural Engineering, focusing on their impact on efficiency, accuracy, and

ethics. The paper will explore the limitations and potential risks of relying solely on machine-generated information as well as the legal and liability implications of using LLMs in Structural Engineering. Finally, the paper will provide mitigation strategies for the responsible use of LLMs Structural Engineering. For this, several prompts were produced and used as an input for ChatGPT. The responses were evaluated for potential risk and liability concerns.

1.1 ChatGPT and other LLMs

Large Language Models (LLMs) are advanced natural language processing models that leverage deep learning. Natural language processing activities, including sentiment analysis, text synthesis, machine translation, and question answering are transformed by LLMs. To customize the model's performance, the training procedure entails pre-training on a vast corpus of text data and fine-tuning on particular downstream tasks.

Modern language model ChatGPT, a variation of the ground-breaking GPT (Generative Pre-trained Transformer) model, was created by OpenAI to engage in interactive conversations and deliver human-like responses. It utilizes deep learning techniques and decoding algorithms that incorporate sampling or beam search techniques to generate the most likely sequence of words based on the context to generate human-like text and engage in interactive conversations. LLMs, including ChatGPT, have demonstrated remarkable capabilities in various domains, such as natural language understanding, translation, and creative writing. ChatGPT has been trained on a vast range of internet text data, enabling it to have a broad understanding of language and generate plausible responses.

Gill and Kaur, 2023 studied the application of ChatGPT in various fields where the use of ChatGPT in Civil Engineering has been left out of discussion. Aluga, 2023 stated the use of ChatGPT in interpretation of complex structural behaviors and performing simulations or modelling of structural systems to help engineers comprehend and interpret complicated structural phenomena. However, challenges and in its implementation have not been discussed. Qadir, 2023 broadly discussed the evolvement of engineering education with artificial intelligence such as ChatGPT. Although, ethical concerns related to the use of AI have been mentioned, centralized focus on Structural Engineering have not been included.

2. Related Literature

This section presents the recent studies on ChatGPT's influence on Structural Engineering. Besides, influence in other fields like academia and health is also discussed. Several studies on artificial intelligence and its effect on Structural Engineering have been carried out. However, ChatGPT and its effect on Structural Engineering is a relatively new topic and remained unexplored. The study has been carried out using several sources like websites, preprint, LinkedIn posts, and YouTube videos all of whose credibility has been verified.

In the book "High Performance Computing in Structural Engineering", Adeli & Soegiarso (1998) discussed the optimization of large structures subjected to the complicated, implicit, and discontinuous constraints of commonly used design codes and standards. Computational models and algorithms that exploit the unique architecture of these LLM's were investigated. Similarly, Alshater (2022) explored the role of artificial intelligence in enhancing academic performance. He explored the potential of artificial intelligence, particularly natural language processing, in enhancing academic performance in economics and finance. He concluded that ChatGPT and similar AI tools can significantly assist researchers in data analysis, interpretation, and communication of findings.

Time and money savings, increased creativity and innovation, enhanced communication and collaboration among researchers are some of the advantages of using ChatGPT for research in the field of Civil Engineering (Banstola, 2023). Dimyadi and Amor (2013) aimed to fill the gap in automated building code compliance checking by focusing on qualitative and quantitative performance criteria in New Zealand's performance-based codes. They discovered that the adoption of an open standard legal data model could alleviate the need for manual updates and maintenance of embedded rules, aligning with the direction taken by standards authorities

globally. However, the paper is limited to a semi-automatic model with a blend of human input and calculations for compliance checking.

With the evolvement of technology and its impact on computational power, Mei & Wang (2021) presented a study on structural optimization in Civil Engineering where they reviewed existing research on structural optimization in the architecture, engineering, and construction industry. Weighting criteria in multi-objective optimization, quantification of optimization objectives, and applicability of optimization algorithms were found as the three major gaps in research involving structural optimization to be addressed in future works.

Following the provided research gaps, Qi et al., (2023) conducted a case study to explore the use of ChatGPT in safety analysis for safety-critical systems, specifically focusing on Systems Theoretic Process Analysis (STPA) applied to Automatic Emergency Brake (AEB) systems. The results demonstrated that incorporating ChatGPT with human experts can improve the analysis, highlighting the potential of LLMs in safety analysis while also identifying challenges for future research in this area.

Although there are ethical issues that need to be resolved, such as the potential biases in generated text answers and lack of contextual understanding, researchers can effectively harness the power of ChatGPT and help the field grow by adhering to a systematic research process and keeping ethical considerations in mind (Banstola, 2023). It is crucial to consider limitations such as generalizability, data quality, ethical considerations, and the need for human analysis and interpretation while using LLMs. Zhou et al. (2023) addressed the ethical concerns associated with ChatGPT, including bias, privacy, and abuse, and provided practical commandments as guidelines for stakeholders using ChatGPT in various applications. Similarly, Akbar & Khan (2023) explored the motivators, demotivators, and ethical aspects of using ChatGPT in providing empirical insights and establishing benchmarks for the ethical incorporation of ChatGPT services in software engineering research, which can ultimately improve software development processes and outcomes.

In addition, ChatGPT has also been the subject of research, with some papers examining its impact on AI research (Joublin et al., 2023). Nawari (2019) proposed a Generalized Adaptive Framework (GAF) with the objectives of developing a theoretical background for the adaptive framework and defining the necessary modules for computerizing the code compliance verification process. The proposed framework aims to automate the code compliance checking process by transforming written code regulations into a computable model using a neutral data standard (Industry Foundation Classes) and overcome the limitations of existing rule-based methods for building design review.

3. Opportunities in Structural Engineering

The use of large language models (LLMs) like ChatGPT in Structural Engineering has gained attention in recent years. ChatGPT can transform the way structural engineers approach the design and analysis of buildings and infrastructure by processing vast amounts of data and providing insights in real time (Frąckiewicz, 2023). It has also been used in safety analysis to address subjectivity in the analysis process (Qi, Zhao and Huang, 2023). ChatGPT's potential in Structural Engineering has led to discussions in online forums, such as Core77 Discussion Boards, where users discuss the tool's capabilities and potential impact on the field (Anon., 2023).

One of the most significant benefits of ChatGPT in Structural Engineering is its ability to analyze and interpret complex data sets quickly and accurately. This means that the AI can rapidly assess the performance of various building materials and design configurations under different conditions. In addition to its data analysis capabilities, ChatGPT can also assist in the development of innovative design solutions that promote earthquake resilience by drawing on its extensive knowledge base (Frąckiewicz, 2023).

3.1 Use in Code-Based Structural Analysis Programs (SAPs)

By responding to prompts with succinct and compact messages, ChatGPT can be utilized to develop effective, repetition-free coding for structural engineering jobs. For instance, it can be used as an assistant to transform design prompts into CADiNP code, a language used in Structural Engineering, by providing examples and

documentation about the syntax of the SOFiSTiK language (Apellaniz, 2023). It can also be used to generate efficient and accurate inputs for STAAD.Pro based on the user's prompts.

For example, a user can ask ChatGPT to generate a 3D model of a structure, and the AI can provide the necessary inputs for STAAD.Pro to create the model (Simplified Learning, 2023). Additionally, ChatGPT can be used to automate mundane tasks like assigning loads, making the process more efficient and less time-consuming. One of its most significant benefits in conjunction with STAAD.Pro is its ability to analyze and interpret complex data sets quickly and accurately.

ChatGPT was asked to generate a code in STAAD.Pro to analyze a rectangular beam with the following prompt. The response is shown in Figure 1. There was no problem while running this code in STAAD.Pro. This can be done for a number of programs that use code-based text editors.

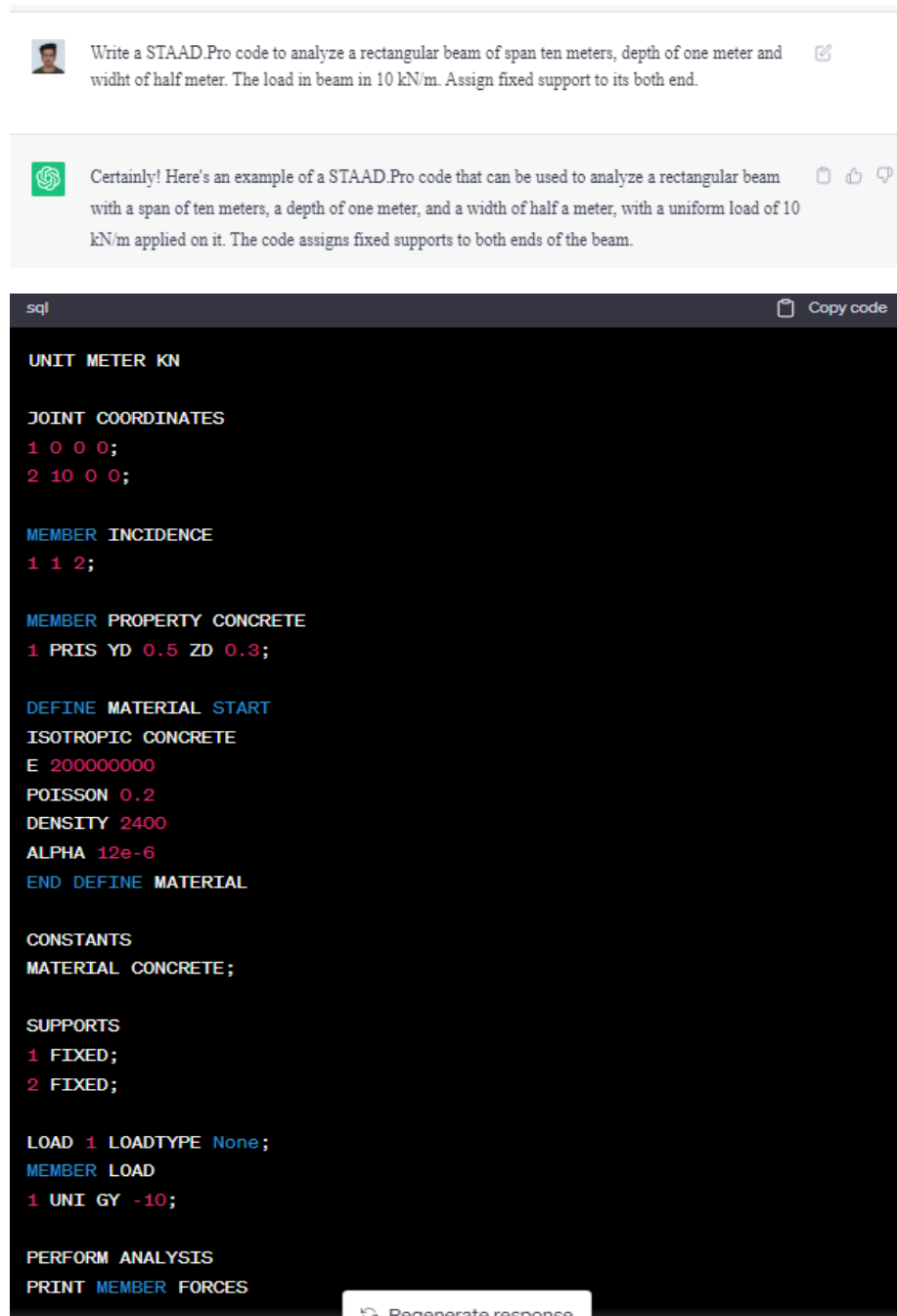


Figure 1: Generation of STAAD.Pro input code using ChatGPT

3.2 Conforming to the Building Code Requirements

Automated building code compliance checking is an area that has received significant attention in research, with some papers exploring the use of AI to automate the process (Dimyadi and Amor, 2013). LLMs can automate the process of code compliance checking by analyzing design inputs and generating reports highlighting potential non-compliance issues. This can streamline the checking process, saving time and reducing human error. A Generalized Adaptive Framework (GAF) has been proposed to automate the building design review process, which involves checking a design against codes and standard provisions to ensure the accuracy of the design and identify any potential issues (Nawari, 2019). Building codes and regulations can be stored in LLMs, providing quick access to the most recent information. In order to assure compliance during the design and construction phases, engineers can benefit from being up to date on the most recent code modifications. Applying ChatGPT to Structural Engineering code compliance checks can increase productivity, accuracy, and safety while ensuring adherence to rules and regulations.

Using ChatGPT, we evaluated the validity of code requirement verification by asking if a building's drift was within a specific range based on the standard codes of the United States of America and Britain.

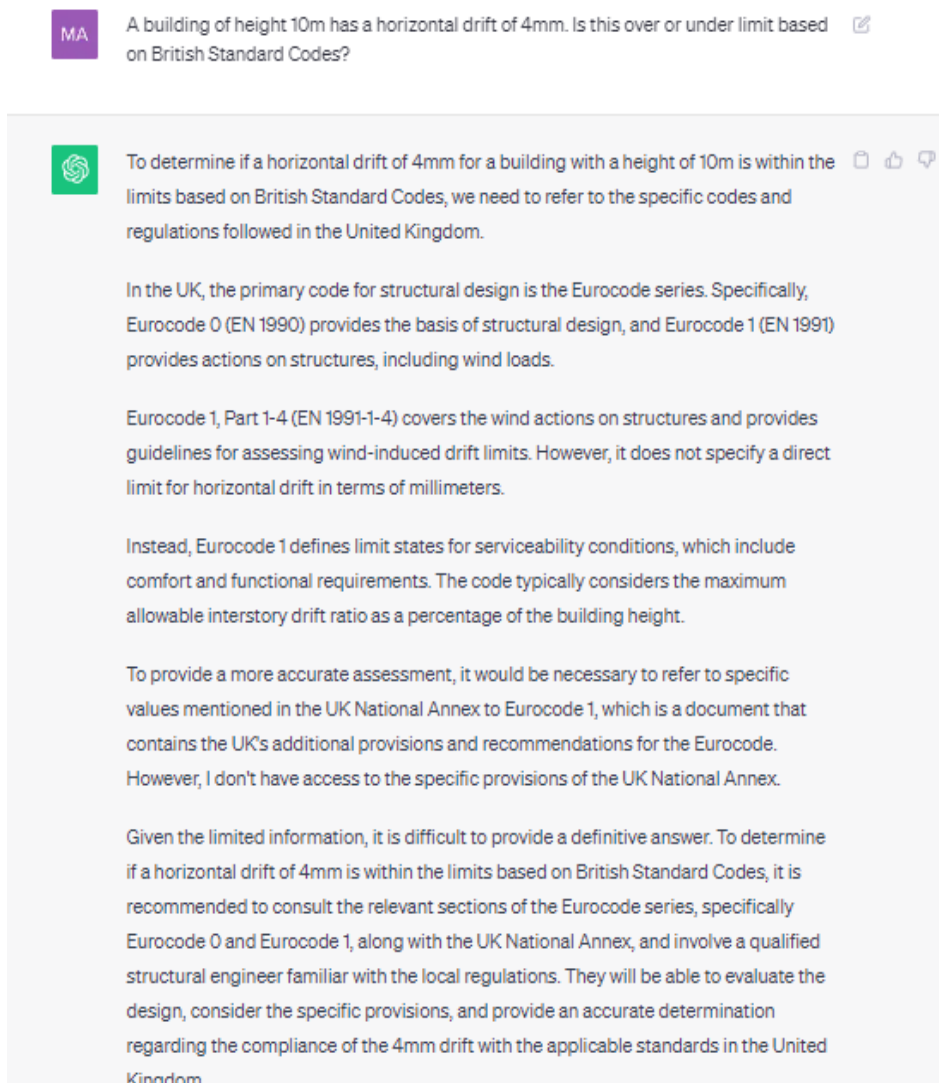


Figure 2: Building's Drift Limit based on British Standard.

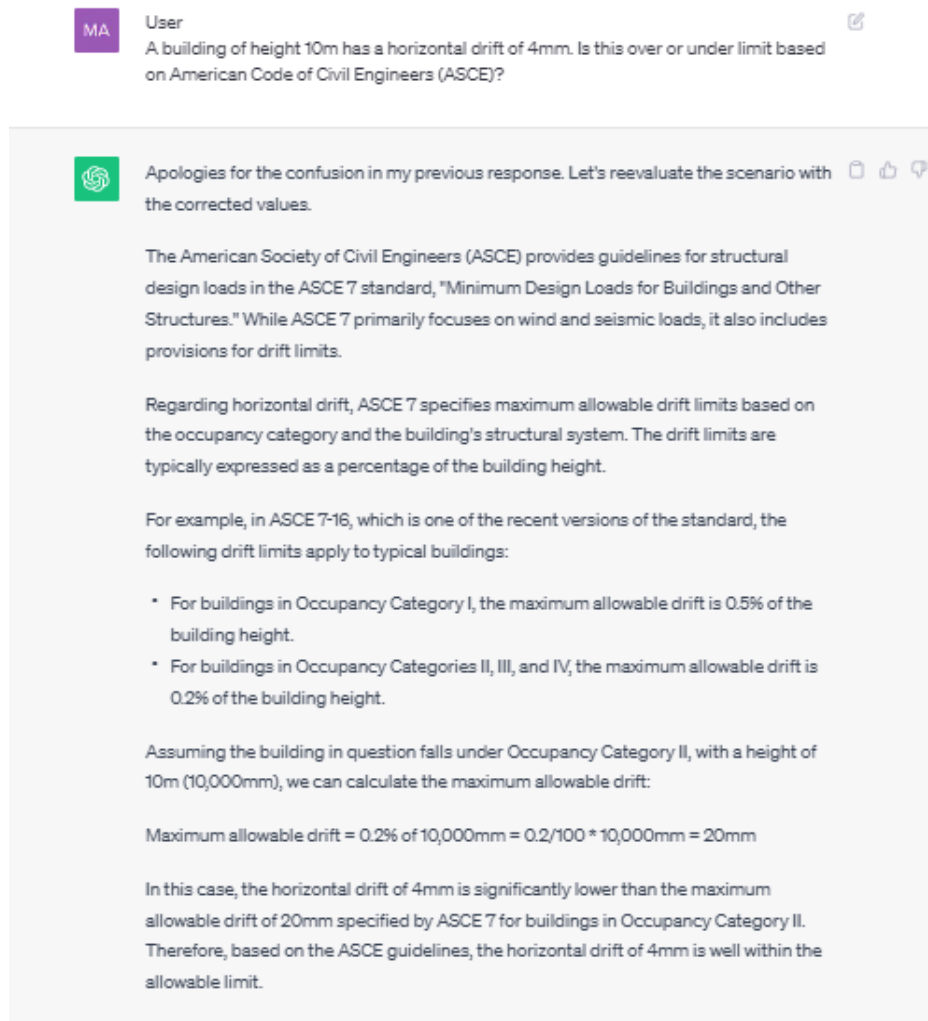


Figure 3: Building's Drift Limit based on American Standard.

3.3 Acts as Knowledge Repository

For structural engineers, ChatGPT and other LLMS can serve as knowledge repositories since they save data on different design codes, design methods, design examples, and design practices that would be time-consuming to obtain manually.



What are the key factors to consider when designing a vertical vessel foundation?



When designing a vertical vessel foundation, several key factors need to be considered to ensure its stability and structural integrity. Here are some of the key factors:



1. **Load Analysis:** Determine the loads acting on the vessel and its foundation. Consider the weight of the vessel, contents, and any additional equipment, such as pipes, insulation, and platforms. Evaluate dynamic loads due to wind, seismic activity, and operational conditions. Determine the maximum and minimum loads to establish design criteria.
2. **Soil Investigation:** Conduct a thorough soil investigation at the site to understand the soil properties and behavior. This includes assessing the soil type, bearing capacity, settlement characteristics, and potential for soil liquefaction. The soil properties influence the foundation design and determine the type of foundation system to be used.
3. **Foundation Type:** Select the appropriate foundation type based on the soil investigation results, load analysis, and design requirements. Common types of foundations for vertical vessels include shallow foundations (such as spread footings or mat foundations) and deep foundations (such as piles or drilled shafts). The choice of foundation type depends on factors such as soil conditions, vessel loads, and local regulations.
4. **Stability Analysis:** Ensure the stability of the foundation by considering factors such as overturning, sliding, and bearing capacity. Analyze the vessel and foundation system for various loading conditions, including wind loads, seismic loads, and operational loads. Verify that the foundation can resist these loads without excessive settlement, tilting, or failure.
5. **Settlement Analysis:** Evaluate the potential settlement of the foundation to ensure that it remains within acceptable limits. Consider the compressibility and consolidation characteristics of the soil to estimate settlement. Excessive settlement can lead to structural problems and impair the performance of the vessel.
6. **Anchorage and Tie-Downs:** Determine if the vessel requires anchorage or tie-downs to resist uplift forces. These may be necessary to counteract wind loads or seismic loads. Design and detail the anchorage system to securely connect the vessel to the foundation.
7. **Construction and Maintenance:** Consider construction techniques, site access, and any specific requirements for construction and maintenance of the foundation. Ensure that the foundation design allows for ease of construction, inspection, and future maintenance activities.
8. **Local Codes and Standards:** Adhere to local building codes, regulations, and industry standards when designing the vessel foundation. Local codes may specify specific design criteria, material requirements, and safety factors that must be followed.

It is crucial to consult with a qualified structural engineer experienced in foundation design and consider the specific project requirements to ensure a safe and reliable design for a vertical vessel foundation.

Figure 4: ChatGPT's reply when asked about critical factors in designing vertical vessel foundation



What are the major differences between ASCE-7 2016 and ASCE-7 2010 editions in the application of wind load?



ASCE-7 (American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures) is a standard that provides guidelines for determining design loads, including wind loads, for various types of structures. The 2016 and 2010 editions of ASCE-7 have some differences in the application of wind loads. Here are the major differences:

1. Updated Wind Speed Maps: One of the significant changes in the 2016 edition is the updated wind speed maps. The maps were revised based on more recent data and improved methodologies for estimating wind speeds. The new maps provide more accurate and refined wind speed values for different regions, which can result in different wind load calculations compared to the 2010 edition.
2. Risk Category Definitions: The 2016 edition introduced revised risk category definitions, which are used to determine the importance of a structure and the corresponding design wind loads. The new definitions include a broader range of structures and clarify the criteria for assigning risk categories. This change may affect the wind load requirements for specific structures.
3. Directionality Factor (K_d): The directionality factor (K_d) used to account for the variation of wind loads with direction has been updated in the 2016 edition. The new edition provides refined values for K_d based on updated research and wind tunnel studies. These changes can lead to different wind load calculations depending on the specific location and wind directionality characteristics.
4. Simplified Wind Load Procedure: The 2016 edition introduced a simplified procedure for determining wind loads on certain types of structures. This procedure, known as the simplified analytical procedure, allows for a more straightforward and less time-consuming calculation of wind loads compared to the detailed procedure. This change provides an alternative approach for smaller and simpler structures.
5. Components and Cladding Loads: The 2016 edition includes updated provisions for components and cladding loads. These loads refer to the wind forces on individual building components, such as walls, roofs, and windows. The new edition provides refined criteria for determining these loads, taking into account factors such as building height, wind exposure, and component dimensions.
6. Enclosure Classification: The 2016 edition introduced the concept of enclosure classification, which classifies buildings based on their degree of enclosure. The level of enclosure affects the internal pressure coefficients used in wind load calculations. This change allows for a more accurate representation of the wind effects on buildings with varying degrees of openness.

It's important to note that these are just some of the major differences between the ASCE-7 2016 and ASCE-7 2010 editions regarding wind load applications. Consulting the specific code and referring to the relevant sections is crucial for accurate and up-to-date information.

Figure 5: ChatGPT's reply when asked about the difference in the application of wind load in two editions of the same code

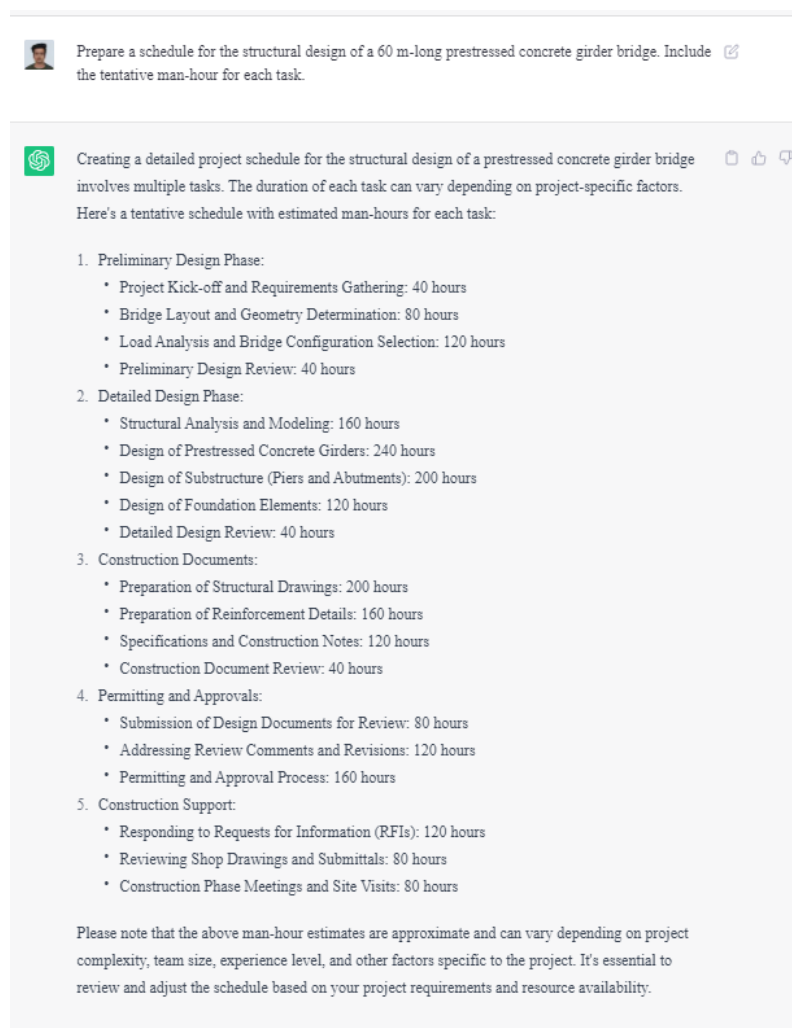
Figure 4 shows the response of ChatGPT when asked about the key factors to be considered while designing a vertical vessel foundation. It was then asked again to list the differences between the application of wind load in the American Society of Civil Engineers (ASCE) 7-2016 edition and the ASCE 7-2010 edition in Figure 5. In an environment where codes are updated every five years or less, structural engineers need to stay updated with the latest changes. While going through everything may be tedious and time-consuming, these LLMs can perform this task smoothly.

3.4 Scheduling and Planning

ChatGPT may aid structural engineers in the scheduling and planning a design project, and it is likely that queries about scheduling and planning may be addressed by the search interface. A structural engineer, for instance, may use Perplexity AI to ask questions regarding scheduling and planning, such as "What is the best way to schedule a design project?" and "What are some efficient planning strategies for a design project?". Project needs, restrictions, and dependencies may be analyzed using ChatGPT, which can then make informed recommendations for project scheduling. Engineers may obtain optimum schedules produced by Perplexity AI by providing project data such as tasks, durations, deadlines, and resource availability. To assist engineers in developing effective project schedules, the AI may consider elements such as job dependencies, critical path analysis, and resource allocation.

Furthermore, Perplexity AI can help project plans be optimized by taking into account numerous elements. To provide recommendations for the most effective distribution of activities and resources, it may examine the project's scope, the available resources, time restraints, and skill needs. Engineers can get the best project results by lowering project length, maximizing resource usage, or cutting expenses with the assistance of this optimization.

The use of ChatGPT in scheduling and planning can potentially improve efficiency, accuracy, and coordination while minimizing errors and increasing the speed of the project. Figure 6 illustrates the scheduling capacity of ChatGPT when asked to schedule a bridge design project.



Prepare a schedule for the structural design of a 60 m-long prestressed concrete girder bridge. Include the tentative man-hour for each task.

Creating a detailed project schedule for the structural design of a prestressed concrete girder bridge involves multiple tasks. The duration of each task can vary depending on project-specific factors. Here's a tentative schedule with estimated man-hours for each task:

1. Preliminary Design Phase:
 - Project Kick-off and Requirements Gathering: 40 hours
 - Bridge Layout and Geometry Determination: 80 hours
 - Load Analysis and Bridge Configuration Selection: 120 hours
 - Preliminary Design Review: 40 hours
2. Detailed Design Phase:
 - Structural Analysis and Modeling: 160 hours
 - Design of Prestressed Concrete Girders: 240 hours
 - Design of Substructure (Piers and Abutments): 200 hours
 - Design of Foundation Elements: 120 hours
 - Detailed Design Review: 40 hours
3. Construction Documents:
 - Preparation of Structural Drawings: 200 hours
 - Preparation of Reinforcement Details: 160 hours
 - Specifications and Construction Notes: 120 hours
 - Construction Document Review: 40 hours
4. Permitting and Approvals:
 - Submission of Design Documents for Review: 80 hours
 - Addressing Review Comments and Revisions: 120 hours
 - Permitting and Approval Process: 160 hours
5. Construction Support:
 - Responding to Requests for Information (RFIs): 120 hours
 - Reviewing Shop Drawings and Submittals: 80 hours
 - Construction Phase Meetings and Site Visits: 80 hours

Please note that the above man-hour estimates are approximate and can vary depending on project complexity, team size, experience level, and other factors specific to the project. It's essential to review and adjust the schedule based on your project requirements and resource availability.

Figure 6: Using ChatGPT to schedule a bridge design project

3.5 Design and Optimization

Design optimization is a critical aspect of Structural Engineering, aiming to find the most efficient and cost-effective structural solutions. LLMs can assist in parametric studies by generating and evaluating various design alternatives based on user-defined criteria. This can accelerate the exploration of a wide range of design options and improve the efficiency of the optimization process. Further, it can also aid in optimizing structural designs based on multiple objectives, such as minimizing material usage, maximizing energy efficiency, or optimizing structural performance under different loading conditions. Providing design recommendations by analyzing historical data and knowledge from expert sources is an essential feature of LLMs that can help engineers identify effective design strategies and innovative approaches, leading to optimized and improved structural designs.

As an illustration, ChatGPT may provide an engineer with a list of all the available materials, their availability in particular area, and other physical attributes so that the engineer can select the best material. Figure 7 shows ChatGPT’s response when asked to list all the available material for building construction.

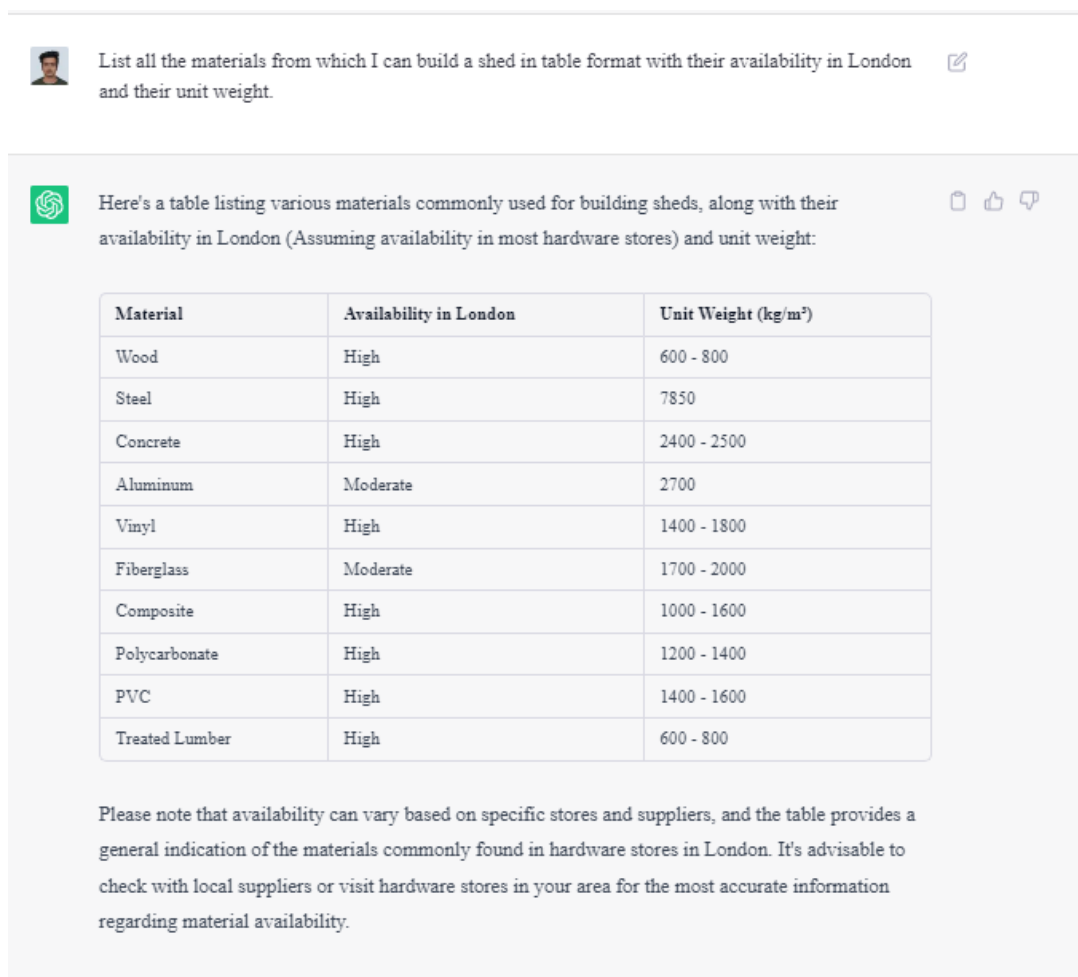


Figure 7: ChatGPT’s reply when asked to list the possible building materials.

4. Risk and Challenges

ChatGPT can significantly contribute to engineering and research as an AI LLM. These powerful tools' functions can be used in a wide range of other fields as well. Nevertheless, despite ChatGPT's many benefits, there are certain drawbacks to using it for structural engineering and research, particularly for design validation and coding. Concerns have been raised concerning ChatGPT's possible application in this industry because it can produce texts in high-level cognitive activities that are almost indistinguishable from writings produced by humans.

4.1 Absence of Most Recent Code Data

ChatGPT and other LLMS models might not have access to the latest recent codes, design methodologies, or design examples because they were trained on big datasets. For structural engineers who must make sure that their designs adhere to the most recent norms and standards, this can be difficult. As shown in Figure 8, when questioned about applying a wind load following ASCE 7-2022, the software was unable to respond since its knowledge base expires after September 2021.

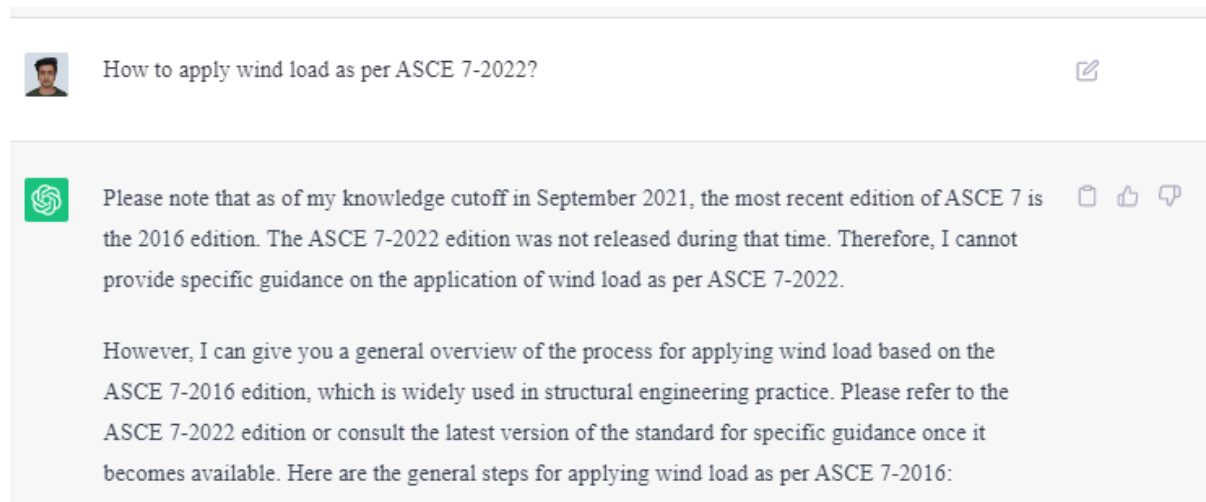


Figure 8: Cutoff of Data after September 2021 in ChatGPT

4.2 Incorrect Referencing

A thorough reference to the correct codes and papers acts as a compass in the complex world of structural engineering, pointing engineers toward reliable data, codes, and standards that sustain the highest levels of performance and safety in their projects. ChatGPT lacks credibility in providing accurate references of the cited text and is unable to correct when mentioned about errors in provided references.

In response to the inquiry about the transition length in prestressed concrete girder bridges, as shown in Figure 9, ChatGPT initially referred to section 5.10.6 of the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications as the source for information on the "Transition Length." However, upon closer examination of the provided clause, as shown in Figure 10, it is evident that section 5.10.6 pertains specifically to the topic of "Transverse Reinforcement for Compression Members" (AASHTO, 2015).



Which American code and clause explains about the transition length in prestressed concrete girder bridges?



The design of prestressed concrete girder bridges, including the consideration of transition lengths, is typically governed by the AASHTO LRFD Bridge Design Specifications. The specific clause that addresses transition length requirements for prestressed concrete girder bridges can be found in the AASHTO LRFD Bridge Design Specifications, Section 5, titled "Concrete Structures."

Within Section 5, the clause that pertains to transition length is typically specified in Article 5.10.6, "Transition Length for Pretensioned Girders." This article provides guidance on determining the required length of transition zones at the ends of prestressed concrete girders.

The AASHTO LRFD Bridge Design Specifications are regularly updated, and the specific clause or article number may vary in different editions. It is essential to refer to the latest edition of the AASHTO LRFD Bridge Design Specifications and consult the relevant section to obtain accurate and up-to-date information on transition length requirements for prestressed concrete girder bridges.

Figure 9: Incorrect Referencing provided by ChatGPT

5.10.6—Transverse Reinforcement for Compression Members

5.10.6.1—General

The provisions of Article 5.10.11 shall also apply to design and detailing in Seismic Zones 2, 3, and 4.

Transverse reinforcement for compression members may consist of either spirals or ties.

5.10.6.2—Spirals

Spiral reinforcement for compression members other than piles shall consist of one or more evenly spaced continuous spirals of either deformed or plain bar or wire with a minimum diameter of 0.375 in. The reinforcement shall be arranged so that all primary longitudinal reinforcement is contained on the inside of, and in contact with, the spirals.

C5.10.6.1

Article 5.10.11.2 applies to Seismic Zone 1 but has no additional requirements for transverse reinforcement for compression members.

Figure 10: Section 5.10.6 of AASHTO

4.3 Lack of Core Knowledge

A significant obstacle to using ChatGPT and other big language models in Structural Engineering is the lack of core domain knowledge. Despite its extensive knowledge base, it is possible that it may lack a thorough understanding of the particular vocabulary and context used in Structural Engineering, which might result in the delivery of information that is either partial or erroneous. As seen in Figure 11, when asked about reinforcement

needed for the column, ChatGPT's reply is to consult a structural engineer as it lacks the core knowledge of the subject.

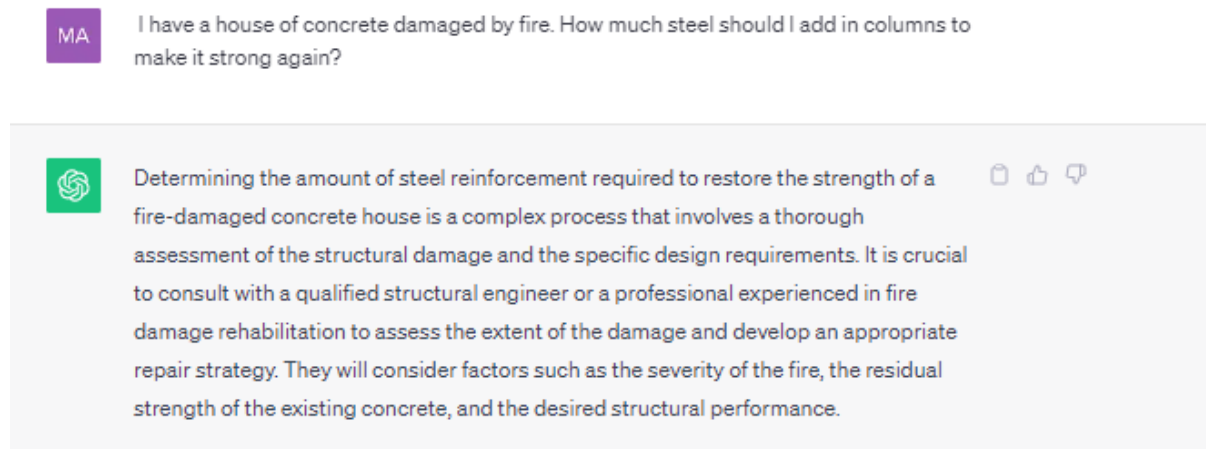


Figure 11: Lack of Expertise in core Structural Engineering concepts.

4.4 Ethical Concerns

Technical know-how, practical experience, and critical thinking are necessary in structural engineering. When AI systems like ChatGPT are used exclusively, there may be worries about an excessive dependence on technology and the risk for declining human abilities and judgment. It is critical to think about AI as a tool that supports engineers rather than taking the place of their knowledge.

From an ethical standpoint, there are also concerns about the use of ChatGPT in the legal and engineering fields. Concerns have been raised regarding the possibility of using ChatGPT to replace actual attorneys and other legal experts, which could harm employment and the economy (Perlman, 2023). Similarly, in the engineering field, the use of ChatGPT and other large language models may raise questions about the qualifications and expertise of the engineer or company, leading to legal and reputational issues (Qi et al., 2023).

When ChatGPT was asked an ethical question from The Institute of Structural Engineer's example ethical scenarios (Anon., 2019), ChatGPT chose an answer which is considered inappropriate according to the institution. Figure 12 shows the response by ChatGPT and Figure 13 shows the institution's response to the question.



1. Dealing with the risk of structural failure



You have discovered an error in the calculations that show a tall building designed by your firm would be at serious risk of collapse in a 50-year wind. The building is complete and occupied. The possibility exists of strengthening the building but at very significant cost to your firm.

Do you:

1. Assess and conclude that the likelihood of a 50-year wind is sufficiently remote and accordingly is not a practical risk.

or

2. Tell the client that the building and the surrounding area should be evacuated until the building has been strengthened.

or

3. Discuss the problem with the client and your Professional Indemnity Insurers and agree to proceed with the strengthening in as discreet a manner as possible accepting the financial consequences.



As a structural engineer, the safety of the occupants and the public is of utmost importance. Given the situation, I would choose option 2: Tell the client that the building and the surrounding area should be evacuated until the building has been strengthened.



While option 1 might suggest that the likelihood of a 50-year wind is remote, it is essential to prioritize the safety of the building and its occupants. Structural failures can have severe consequences, and it is our professional responsibility to mitigate potential risks.

Option 3, discussing the problem with the client and insurers and proceeding with discreet strengthening, might not adequately address the urgency of the situation. Evacuating the building until the necessary strengthening measures are taken ensures the immediate safety of occupants and prevents any potential catastrophic events.

Though strengthening the building may come at a significant cost to the firm, the potential consequences of a collapse far outweigh the financial implications. By evacuating the building, we can minimize the risk and work towards rectifying the structural deficiencies appropriately.

Figure 12: ChatGPT's response for an ethical question in structural engineering.

1. Dealing with the risk of structural failure

You have discovered an error in the calculations that show a tall building designed by your firm would be at serious risk of collapse in a 50-year wind. The building is complete and occupied. The possibility exists of strengthening the building but at very significant cost to your firm.

Do you:

- Assess and conclude that the likelihood of a 50-year wind is sufficiently remote and accordingly is not a practical risk.
- Tell the client that the building and the surrounding area should be evacuated until the building has been strengthened.
- Discuss the problem with the client and your Professional Indemnity Insurers and agree to proceed with the strengthening in as discreet a manner as possible accepting the financial consequences.

Clarification and discussion points

SUMMARY OF THE ETHICAL ISSUE

The wellbeing of those using and around the building is paramount regardless of the costs involved.

INAPPROPRIATE RESPONSE(S)

- The risk of personal injury is too great to assume that the likelihood of a 50-year wind is fairly remote and do nothing.
- This option does not address the imminent risk and consequences of structural failure.

Figure 13: The Institute of Structural Engineer's response to same question from Figure 12

Source: (Anon., 2019)

5. Mitigation Strategies

To address the risks and challenges associated with the use of ChatGPT and other large language models in Structural Engineering, several mitigation strategies have been proposed.

5.1 Use of Appropriate Prompts

Structural engineers can avoid many risks and challenges considerably by using the suitable prompts and getting the most out of ChatGPT and other LLMs. Structural engineers can direct GPT to provide more accurate and helpful results by giving precise and pertinent suggestions. For instance, prompts might be used to request that GPT offer design suggestions, examine structural weaknesses, or offer solutions to challenging engineering issues. One example of how using the right prompt can be beneficial is presented here. Similar questions were asked to ChatGPT about the thickness of the wooden deck, where the difference in reply when using subtle differences in prompt can be seen in Figure 14 and Figure 15.



How thick should the deck of my porch for storing sacks of rice be?



The thickness of the deck for your porch, specifically for storing sacks of rice, will depend on several factors, including the weight of the sacks, the spacing of the supports, and the type of materials you plan to use for the deck. However, I can provide you with some general guidelines to help you determine an appropriate thickness.

1. Calculate the weight: Determine the weight of the sacks of rice you intend to store on the deck. Multiply the weight of a single sack by the number of sacks you plan to store. This will give you the total weight that the deck needs to support.
2. Determine the load-bearing capacity: Consult the manufacturer's specifications or consult with a structural engineer to determine the load-bearing capacity of the materials you intend to use for the deck. This will help you understand how much weight the deck can safely support.
3. Consider spacing and support: The spacing of the deck supports or joists will also influence the thickness requirements. If you have wider spacing between supports, you may need a thicker deck to distribute the weight more evenly and prevent sagging or structural issues.
4. Consult local building codes: Check your local building codes and regulations, as they may specify minimum requirements for deck thickness and load-bearing capacities.
5. Seek professional advice: If you are uncertain about the appropriate thickness for your specific situation, it is advisable to consult with a structural engineer or a professional contractor. They can evaluate your porch's design, the weight requirements, and other factors to provide you with precise recommendations.

Remember, these are general guidelines, and the specific requirements for your porch deck may vary based on the factors mentioned above. Taking safety and structural integrity into consideration is crucial to ensure that your deck can adequately support the weight of the rice sacks and any other intended use.

Figure 14: ChatGPT's response when using a less detailed prompt.



How thick should the deck of my porch made from timber wood be for storing 10 sacks of rice bags each weighing 100KGS?



The thickness of the deck for your porch would depend on several factors, including the type and quality of the timber wood you're using, the spacing of the supporting joists, and the expected load-bearing capacity of the deck. However, I can provide you with some general guidelines.

To determine the appropriate thickness, you'll need to consider the total weight of the rice sacks, as well as any additional weight that may be applied to the deck, such as furniture or people. Let's calculate the total weight of the rice sacks:

$$10 \text{ sacks} * 100 \text{ kg/sack} = 1000 \text{ kg}$$

Now, it's essential to account for a safety factor to ensure the stability and longevity of the deck. A commonly used safety factor for residential decks is 40 pounds per square foot (psf), which is roughly equivalent to 195 kg per square meter (kg/m²).

Assuming an average-sized deck area, we can estimate the required thickness. However, keep in mind that these are rough estimates, and it's always a good idea to consult with a professional engineer or builder for accurate calculations specific to your situation.

1. Determine the area covered by the rice sacks:

Let's assume the rice sacks are evenly distributed across the deck, and each sack occupies an area of approximately 1 square meter. Therefore, the total area covered by the sacks would be 10 square meters.

2. Calculate the total weight applied to each square meter:

$$\text{Total weight of rice sacks} / \text{Area covered by sacks} = 1000 \text{ kg} / 10 \text{ m}^2 = 100 \text{ kg/m}^2$$

3. Consider the safety factor:

To determine the minimum thickness, divide the weight applied to each square meter by the safety factor:

$$100 \text{ kg/m}^2 / 195 \text{ kg/m}^2 \approx 0.51$$

Based on these calculations, a deck made from timber wood should have a minimum thickness of approximately 0.51 meters (or approximately 51 centimeters) to safely support the weight of the rice sacks. Remember, this is just a rough estimate, and you should consult a professional to ensure your deck is structurally sound and meets local building codes.

Figure 15: ChatGPT's response when using a detailed prompt

5.2 Augmenting large language models with expert knowledge

Another strategy to solve the limits of these models is to provide these LLMs with adequate information on fundamental as well as core structural engineering concepts. Engineers can guarantee that the models deliver accurate and trustworthy information and solutions by embedding domain expertise into the models. Additionally, a unique LLM that specializes in structural engineering can be developed.

5.3 Developing regulatory frameworks and guidelines

Various organizations and regulating bodies working for the betterment of structural engineering can develop regulatory frameworks and guidelines for the development and use of large language models in this field. This

ensures that these models are safe, reliable, and ethical. This can include establishing legal and liability frameworks, ethical guidelines, and regulatory standards for the development and use of these models.

6. Conclusion and Key Takeaways

The advancements in high-performance computing (HPC) and large language models (LLMs) like ChatGPT have the potential to revolutionize the field of Structural Engineering. Use of LLMs, such as ChatGPT in Structural Engineering, including but not limited to code based structural analysis programs, code compliance, knowledge repository and planning as well as scheduling of construction, it should be supported by experience and intelligence of Structural Engineer at each level. It is crucial to address the concerns that arise from relying solely on machine-generated information. Biases, misinformation, safety, reliability, and the lack of domain expertise in LLMs can pose significant risks.

Hence, careful management of LLMs is necessary to prevent the generation of harmful or inappropriate content. Collaborating with human experts, establishing guidelines and standards is vital to address ethical concerns related to bias, privacy, and abuse. Continuous monitoring and updating of LLMs are necessary to maintain the accuracy and relevance of the information they generate.

Hence, while ChatGPT and LLMs offer tremendous benefits in Structural Engineering, their responsible usage and integration with human expertise are crucial. By harnessing the full potential of LLMs while mitigating risks, the field can embrace efficient and safe engineering practices in line with ethical considerations.

7. References

- Apellániz, D. (2023, 05 17). *SOFiSTiK for you*. Retrieved from Revolutionise Structural Engineering with ChatGPT and SOFiSTiK: <https://sofistikforyou.com/revolutionise-structural-engineering-with-chatgpt-and-sofistik/>
- AASHTO. (2015). *AASHTO LRFD Bridge Design Specifications (7th ed.)*. American Association of State Highway and Transportation Officials.
- Akbar Azeem, M., Khan Ali, A., & Liang, P. (2023, 08 13). Ethical Aspects of ChatGPT in Software Engineering Research. *IEEE Transactions on Artificial Intelligence*(PrePrint). doi:<https://doi.org/10.48550/arXiv.2306.07557>
- Alshater, M. (2022, December 22). Exploring the Role of Artificial Intelligence in Enhancing Academic Performance: A Case Study of ChatGPT. *Social Science Research Network*, 22. doi:<https://dx.doi.org/10.2139/ssrn.4312358>
- Aluga, M. (2023). Application of CHATGPT in civil engineering. *East African Journal of Engineering*, 6(1), 104–112. <https://doi.org/10.37284/eaje.6.1.1272>
- Banstola, P. (2023, 04). A Review on Exploring the Use of ChatGPT in Civil Engineering Research using ChatGPT. doi:10.13140/RG.2.2.29908.07047
- Choudhury, A., & Shamszare, H. (2023). Investigating the Impact of User Trust on the Adoption and Use of ChatGPT: Survey Analysis. *J Med Internet Res*, 25, e47184. <https://doi.org/10.2196/47184>
- Core77 . (2023). Retrieved from chatGPT/LLM - Design Prompt Engineering: <https://boards.core77.com/t/chatgpt-llm-design-prompt-engineering/81973>
- Dimyadi, J., & Amor, R. (2013). Automated Building code Compliance Checking Where is it at? . *Proceedings of CIB WBC 2013*, (pp. 172-185).
- Frackiewicz, M. (2023, 05 01). *TS2 Space*. Retrieved from How ChatGPT is Enhancing the World of Structural Engineering and Earthquake Resilience: <https://ts2.space/en/how-chatgpt-is-enhancing-the-world-of-structural-engineering-and-earthquake-resilience/>

- IStruct.* (2019). Retrieved 05 31, 2023, from Example ethical scenarios: <https://www.istructe.org/resources/guidance/example-ethical-scenarios/>
- Joublin, F., Ceravola, A., Deigmoell, J., Gienger, M., Franzius, M., & Eggert, J. (2023, 05 10). A Glimpse in ChatGPT Capabilities and its impact for AI research. arXiv. doi:<https://doi.org/10.48550/arXiv.2305.06087>
- Mei, L., & Wang, Q. (2021, February 13). Structural Optimization in Civil Engineering: A Literature Review. *Buildings*, 11(2), 66. doi:<https://doi.org/10.3390/buildings11020066>
- Nawari, N. (2019). A Generalized Adaptive Framework (GAF) for Automatic Code Compliance Checking. *Buildings*, 9(4), 86. doi:<https://doi.org/10.3390/buildings9040086>
- Perlman M., A. (2022, December 21). The Implications of ChatGPT for Legal Services and Society. *Social Science Study Network*, 24. doi:<https://dx.doi.org/10.2139/ssrn.4294197>
- Prieto, S. A., Mengiste, E. T., & García de Soto, B. (2023). Investigating the Use of ChatGPT for the Scheduling of Construction Projects. *Buildings*, 13(4). <https://doi.org/10.3390/buildings13040857>
- Plevris, V., & Tsiatas C., G. (2018, April 10). Computational Structural Engineering: Past Achievements and Future Challenges. *Frontiers in Built Environment*, 4. doi:<https://doi.org/10.3389/fbuil.2018.00021>
- Qi, Y., Zhao, X., & Huang, X. (2023, April 3). Safety Analysis in the Era of Large Language Models: A Case Study of STPA using ChatGPT. arXiv. doi:<https://doi.org/10.48550/arXiv.2304.01246>
- Simplified Learning (Director). (2023). *Can AI answer my Civil Engineering Questions ??? Using ChatGPT for my Civil Engineering queries.* [Motion Picture]. Retrieved May 24, 2023, from <https://www.youtube.com/watch?v=xO3-mnBDqJk>
- Qadir, J. (2023). Engineering Education in the Era of ChatGPT: Promise and Pitfalls of Generative AI for Education. 2023 *IEEE Global Engineering Education Conference (EDUCON)*, 1–9. <https://doi.org/10.1109/EDUCON54358.2023.10125121>
- Yoshimura, S., Hori, M., & Oshaki, M. (1998). *High-Performance Computing for Structural Mechanics and Earthquake/Tsunami Engineering*. CRC Press. doi:10.1007/978-3-319-21048-3
- Zhou, J., Müller, H., & Andreas Holzinger, F. (2023, May 18). Ethical ChatGPT: Concerns, Challenges, and Commandments. doi:<https://doi.org/10.48550/arXiv.2305.10646>