Undergraduate Thesis Prospectus

ASCE Student Steel Bridge Competition

(technical research project in Civil Engineering)

The Promotion of Mass Timber as a Substitute for Structural Steel

(sociotechnical research project)

by

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On my honor as a University of Virginia student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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STS Advisor: Peter Norton, Department of Engineering and Society

General Research Problem

How can the environmental cost of structural steel be reduced?

Steel is a common building material because of its design versality, ease of prefabrication, durability, and strength-to-weight ratio. But the manufacturing process has a substantial carbon footprint. Designers have tried to mitigate this impact by using recycled steel, but the environmental effects are still severe. The U.S. consumption rate of construction materials exceeds the world sustainable usage rate, meaning we are at risk of material shortages (Horvath, 2004). This has led to the exploration of alternative materials with comparable stiffness and strength to steel, but lower net carbon emissions during production.

ASCE Student Steel Bridge Competition

What is the most competitive steel bridge design that our team can feasibly conceive and construct as our entry in the 2025 ASCE Steel Bridge competition?

My capstone project is the ASCE Steel Bridge Design Competition, where our group will design, fabricate, and load test a steel bridge. I will be working alongside Cooper Davenport, Bear Matheson, Ben Van Zandt, Eric Venner, and Wren Sadler, under the faculty advisement of Jose Gomez in the Civil Engineering Department at UVA. We are to create a 1:10 scale model of a steel bridge that will span across a river corridor in Story County, Iowa. The optimal site has a protected island in the middle of the span that we are unable to interfere with during construction. The goal is to minimize the deflection, cost, construction time, weight, and number of builders.

We use Revit to draft structural drawings of the bridge design, which include plans, sections, a 3D rendered view, and a detail sheet for bolted connections. The analytical model in RAM Elements is used for finding the weight, displacement, and member stresses. Both the

analysis results and feedback from professional/faculty mentors are taken into consideration as we modify our design. Our team also attended safety training to prepare for the fabrication stage of the project. We reached out to a contact at Liphart Steel for a cost estimate on the first draft of our design, which we then cited in a proposal to the UVA Experiential Learning Fund. Ideally the final design will be cost-effective, stiff, light, easy constructible, and fit within the dimensional constraints in the competition rules. Once the bridge is built, we will load-test it in the Civil Engineering lab to ensure it is ready for competition.

The Promotion of Mass Timber as a Substitute for Structural Steel

How have proponents of structural mass timber promoted it as a "green" alternative material to steel in new construction?

Mass timber, a material made from layering and gluing together structural lumber boards, is a cost-competitive alternative to steel. Because of its ability to sequester carbon, mass timber has lower net carbon emissions, and the cross-laminating of the wood layers makes it just as strong. A 100% market adoption scenario estimated a reduction of 497-825 million tons of CO_2 emissions from mass timber building construction from 2020 to 2070. The projected carbon benefit was based off the emission difference between mass timber and concrete during raw material extraction and construction/installation, and the estimated amount of carbon stored in mass timber over its life cycle (Nepal et al. 2024). A life-cycle impact analysis on 1 m^3 of glulam timber found a reduced reliance on fossil fuels and an increase in renewable energy compared to typical construction materials. It also showed the amount of carbon sequestered in the wood far exceeded the number of emissions produced during the manufacturing process (Bowers et al. 2017). Published life-cycle analysis results have concluded that mass timber manufacturing results in more greenhouse gas emissions than standard lumber and wood panels, due to the

energy needed for material transport, drying, cutting, gluing, assembling, etc. But the emissions produced are less than that for steel and concrete (Nepal et al. 2024). Due to the variation material properties of mass timber members, analytical models of these structures can be unreliable. As a result, a more conservative design approach would have to be used.

One participant is the Natural Resources Defense Council (NRDC), a sustainability advocacy that "works to safeguard the earth—its people, its plants and animals, and the natural systems on which all life depends" (NRDC, 2024). The NRDC doesn't oppose wood construction if it is sourced legally and harvested using methods that protect forest species, the local water quality, and the rights of indigenous people. They claim the best practice is to buy recycled lumber and request documentation of its source from the seller (MacMillan, 2016). The NRDC also supports policies to advance "carbon capture and storage," a technique to capture CO_2 pollution and permanently bury it underground (Doniger, 2018). Mass timber buildings have this same effect naturally. Another participant is American Forests, an environmental advocacy whose mission is to "create healthy and resilient forests...that deliver essential benefits for climate, people, water, and wildlife." Their stance is that forests are the best solution for climate change because they capture and store almost 15% of the country's carbon emissions (American Forests, 2024). They support mass timber construction because wood as a building material has the same carbon-storing capacity (American Forests, 2019).

Some trade associations include the International Association for Mass Timber Construction, the first global group that offers training, certifications, and education in order to promote the mass timber construction movement (IAMTC, 2024). Mass Timber Strategy provides technical guides for mass timber construction, embodied carbon & life cycle analyses, and biophilic design. They also founded Mass Timber Marketplace, which consolidates contacts for mass timber providers into one website (MTS, 2021). Boston Mass Timber Accelerator

invests in mass timber construction projects, raises public awareness of its economic and carbon benefits, and introduces practitioners to the feasibility of mass timber design and construction (BPDA, 2024). The Mass Timber Construction Management Program from Woodworks provides one-on-one assistance with wood construction projects and offers tools to help improve design and management. It includes two elements: a project management curriculum and a mass timber installation training (Woodworks, 2024). The American Wood Council (AWC) creates the national design specifications for wood design, and just added the Mass Timber AMM Guide in 2023 to be used with the Florida Building Code. They provide guides for fire safety, acoustics, connections, energy efficiency, green building, resilience, etc. Other tools include a carbon calculator, reused wood directory, and forest product data visualization (AWC, 2024). They were the first industry to develop third-party verified environmental product declarations that describe the environmental impact of their materials. They market wood as a "carbon-friendly solution to existing structural materials" (AWC, n.d.).

A significant participant in the mass timber movement is the American Insitute of Steel Construction (AISC). They market structural steel as a sustainable choice, claiming it's "93% recycled content and is 100% recyclable, making it a material that is circular for generations." Since all hot-rolled sections in the U.S. are made in electric arc furnaces, "the American steel industry is the least carbon-intensive of all major steel-producing countries." The major American steel mills have emphasized their commitment to the decarbonization of the structural steel industry. Nucor pledges to reduce greenhouse gas intensity by 35% by 2030, Steel Dynamics pledges to go carbon neutral by 2050, and Cleveland Cliffs pledges to reduce greenhouse gas emissions by 25% by 2030. AISC supports structural steel as the most sustainable choice because it "is the most recycled material on the planet" (AISC, n.d.).

Another influential participant is the U.S. Green Building Council (USGBC), who created the LEED rating system. According to USGBC, “LEED certification provides a framework for healthy, highly efficient, and cost-saving green buildings, which offer environmental, social and governance benefits.” Their goal is to reduce the contribution to climate change, enhance individual human health, protect water resources, enhance biodiversity, promote sustainable material cycles, and enhance community quality of life. A project can achieve LEED certified, silver, gold, or platinum status based on points earned during a review by Green Business Certification Inc (GBCI). The credits address carbon, energy, water, waste, transportation, materials, health and indoor environmental quality (USGBC, 2024). The USGBC also provides online courses, memberships, and credentials for designers. They also require AISC to submit environmental product declarations to ensure the environmental impact of the steel products is accurate and transparent. The USGBC supports the use of mass timber in new construction because it “helps with our shift to renewable resources.” They claim the economic benefits include off-site fabrication, shorter construction time, and lower material costs. The aesthetics of exposed wood also resulted in higher occupant satisfaction since “humans are attracted to natural shapes, forms, and textures.” However they address the challenges of adopting a new material, such as a limited supply of mass timber in North America, limited industry experience, and lack of testing data (Holt, 2017).

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