Sustainable Seismic Architecture:
Exploring the Synergy of Mortise-and-Tenon Joinery and Modern Timber Construction for Reducing Embodied Carbon

A thesis submitted in partial fulfilment of the requirements for the degree Master of Architecture in the Department of Architecture of the Rhode Island School of Design.

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2023

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Abstract

This design thesis explores the potential of combining ancient Mortise-and-Tenon joinery techniques with modern timber construction to create sustainable seismic architecture that simultaneously reduces embodied carbon. By studying the enduring qualities of Mortise-and-Tenon structures and their ability to withstand earthquakes, this research uncovers a synergistic relationship between traditional joinery methods and contemporary building materials, unlocking significant opportunities for embodied carbon reduction ranging from 7 to 40% compared to other modern architecture construction.

The research reveals that Mortise-and-Tenon structures commonly incorporate large roof systems, acting as mass dampers that provide flexibility and distribute weight evenly to columns. By transferring the substantial roof load to the columns, these structures exhibit a dynamic interaction with the surrounding landscape. Inspired by this discovery, the subsequent phase of the thesis focuses on modern large roof architecture, with a commitment to incorporating wisdom from the past and exploring possibilities for the future.

Practical design solutions derived from the knowledge and insights gained throughout the research are crucial. Therefore, the final design proposal centers around a high school in Chula Vista, California, with particular emphasis on the gymnasium building. By reinterpreting traditional structures with new materials such as cross-laminated timber (CLT), the design seeks to address seismic threats while honoring the legacy of the past.

In summary, this thesis presents a design approach that harnesses the sustainable qualities of Mortise-and-Tenon joinery and integrates them with modern timber construction to create earthquake-resistant structures with reduced embodied carbon. The research highlights the significance of embracing innovative methods to achieve truly green and sustainable architecture. By sharing the highlights, valuable insights, and outcomes of this thesis project, the presentation aims to inspire the audience and foster a deeper understanding of the transformative potential of sustainable seismic architecture.


Flexibility of the Wooden Structure

The construction detail model of a part of ancient Chinese palace wooden structure.
The columns of the structures in the Forbidden City, the experimental model, are not deeply embedded underground, which allows them a certain degree of movement and can prevent structural collapse due to a broken column.
Tenon-Mortise joints for fixing vertical structural components

Tenon-Mortise joints for joining intersecting horizontal structural components

Tenon-mortise joints for joining horizontal and vertical structure components

Tenon-Mortise joints for joining boards
HONGAN-JI HONDOU, KYOTO
PHRASE ONE DESIGN:
Design of a wall using Mortise and Tenon joints
KEY TAKE AWAY AND NEXT STEP

I discovered that most Mortise and Tenon structures feature a large roof system that accounts for approximately one-third or even half of the building's overall structure. Therefore, these structures always have a big roof which acts as a mass damper with connections that allows for flexibility. The remarkable aspect is that when the weight of such a substantial roof is evenly transferred to the columns, these columns act as if they are riding on the landscape.

BIG ROOF ARCHITECTURE
NEUE NATIONALGALERIE, GERMANY
DESIGN SITE

Chula Vista, California
Second Largest City in San Diego County.
Chula Vista, California, is situated in close proximity to several active fault lines, making them susceptible to seismic activity and earthquakes. The region lies within the tectonic boundary where the Pacific Plate and the North American Plate interact, resulting in ongoing geological stress and movement. Here are some key aspects regarding the seismicity and earthquake threats in the area:
1. Rose Canyon Fault: The Rose Canyon Fault is the most prominent fault line in the region and runs along the coastline of San Diego. It is an active right-lateral strike-slip fault capable of generating significant earthquakes. The fault poses a potential seismic hazard to densely populated areas of San Diego, including Chula Vista.

2. Newport-Inglewood/Rose Canyon Fault Zone: This fault zone is a complex network of interconnected faults, including the Rose Canyon Fault. It extends offshore along the coast and has the potential to produce earthquakes of magnitude 6.5 or greater. The proximity of this fault zone to Chula Vista increases the seismic risk to the area.

3. Southern San Andreas Fault: Although located further inland, the Southern San Andreas Fault system is geologically significant and poses a seismic threat to the broader Southern California region. While it doesn't directly impact Chula Vista, it contributes to the overall seismic activity and serves as a reminder of the seismic hazards present in the area.

4. Earthquake History: The region has experienced notable earthquakes in the past. The most significant recent event was the magnitude 7.2 earthquake that occurred in the Mexicali-Calexico area in 2010. Although the epicenter was located across the border in Mexico, the earthquake was felt strongly in Chula Vista and other parts of San Diego County.
Given the proximity to fault lines and the history of seismic activity, it is essential for architects, engineers, and urban planners in the San Diego and Chula Vista areas to consider seismic design principles and strategies when designing and constructing buildings. Implementing measures to enhance structural resilience and ensure the safety of occupants during earthquakes is crucial in mitigating potential risks and minimizing the impact of seismic events.
WORM'S EYE VIEW
### Mortise and Tenon Structure

#### Detail Construction

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<td>1</td>
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#### Mortise and Tenon Structure

#### Detail Construction - Part One

1. [Image of assembly process]
2. [Image of assembly process]
3. [Image of assembly process]
4. [Image of assembly process]


Facilities Master Plan—SRG Partnership. (n.d.).


