VERMONT TECHNICAL COLLEGE

Bachelor of Science in

Architectural Engineering Technology

&

Bachelor of Science in

Renewable Energy

Combined Capstone Senior Design Projects

(2022)

Performing Arts Facility

Sydney, Australia

(1) Integrated Sustainable Building Design

(2) Structural Engineering Design

The following summaries describe two team projects that are being undertaken by students from the Architectural Engineering Technology and Renewal Energy programs, working together this semester. They will be updated later in the semester when the design work is substantially complete.

(1) Integrated Sustainable Building Design

ARE 4720

Senior Project

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Our team is designing a sustainable and energy efficient building for the 2022 ASHRAE Design Competition. This project entails designing architectural, structural, HVAC, electrical, lighting, and civil systems. The building is a net zero performing arts facility for the city of Sydney, Australia. This project is a university based performing arts center with two levels above grade and one below grade. Our main priority is for the building to be net zero.

The address for our building site is 1005 City Road, Sydney, Australia. This site is anywhere from 82 to 85 feet above sea level. This means our site is at a minimal risk of flooding. Large tsunamis in this area are extremely unlikely to occur according to Geoscience Australia. Based on their data, for most of New South Wales a 40 cm (about 1.31 ft) maximum wave from tsunami activity will occur once every 100 years. Earthquakes are also a minimal risk as Sydney is located on a stable tectonic plate.

In terms of incoming traffic and transportation to our site, we will focus on foot traffic and some motor vehicle traffic. The city of Sydney has a small population of households that own cars compared to the rest of Australia. About 35.4% do not own a car while the total average number of households without cars for all of Australia is 7.5%. The two most popular modes of public transportation in Sydney are train and bus, which this location already has three bus stations within 1,000 feet. People who own cars are still likely to use public transportation. Based on these statistics, we can expect more traffic to be foot based rather than vehicle based.

No additional electrical plants will be added to our design. Because of this, other forms of renewables were not considered like wind, hydro, and bioenergy. Due to the additional cost and complexity of geothermal, we will not be implementing it into our design. With the amount of sun hours Sydney gets, we plan to utilize solar energy to power our building. The photovoltaic system will be grid-tied to alleviate the associated costs of a large battery bank. Petroleum products are typically imported from nearby countries such as Malaysia, Indonesia, New Zealand, and Papua New Guinea. Sydney is climate zone 4A so we will conform to all applicable codes for this climate zone. Cooling is a priority in Sydney as the low temperatures for Sydney are in the range of 47F-67F. Codes and regulations we must consider while designing are ASHRAE 2019 standards 15, 34, 55, 62.1, 90.1, 189.1, IBC 2015, NEC NFPA 70, Net Zero Energy, and the Building Code of Australia.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	22.8 °C (73.1) °F	22.6 °C (72.6) °F	21.3 °C (70.4) °F	18.8 °C (65.9) °F	15.8 °C (60.4) °F	13.6 °C (56.5) °F	12.7 °C (54.9) °F	13.5 °C (56.4) °F	16 °C (60.8) °F	18 °C (64.5) °F	19.7 °C (67.4) °F	21.4 °C (70.6) °F
Min. Temperature °C (°F)	20.2 °C (68.3) °F	20.1 °C (68.2) °F	18.8 °C (65.8) °F	16 °C (60.8) °F	12.7 °C (54.8) °F	10.9 °C (51.7) °F	9.6 °C (49.2) °F	10 °C (50) °F	12.4 °C (54.2) °F	14.6 °C (58.3) °F	16.7 °C (62) °F	18.5 °C (65.3) °F
Max. Temperature °C (°F)	26.1 °C (79.1) °F	25.5 °C (77.8) °F	24.2 °C (75.5) °F	21.8 °C (71.3) °F	19.2 °C (66.6) °F	16.8 °C (62.2) °F	16.4 °C (61.5) °F	17.5 °C (63.5) °F	20 °C (68) °F	21.9 °C (71.4) °F	23.2 °C (73.8) °F	24.9 °C (76.9) °F
Precipitation / Rainfall mm (in)	79 (3.1)	105 (4.1)	86 (3.4)	89 (3.5)	85 (3.3)	101 (4)	57 (2.2)	59 (2.3)	54 (2.1)	59 (2.3)	77 (3)	61 (2.4)
Humidity(%)	70%	74%	73%	72%	70%	71%	69%	65%	65%	64%	69%	69%
Rainy days (d)	7	8	10	9	8	8	6	6	6	7	7	7
avg. Sun hours (hours)	9.0	8.5	8.1	7.9	8.0	7.3	7.8	8.5	9.2	9.2	9.3	9.6

Sydney Weather by Month

Since we are designing a performing arts facility, it is important to keep in mind noise while we design our mechanical systems and pick our finishes. We would like to avoid any sort of vibration, humming, or echos in spaces where acoustics need to be prioritized. To minimize unwanted noise in the theaters, we will have two separate HVAC systems. One system will be for office spaces where noise cancelling is not a priority. The other system will be for the theaters where noise cancelling, and ventilation will be a priority. In Sydney, the humidity is around 70% so using the proper air and ventilation systems, like ones in museums and theaters, will keep the occupants comfortable and the room intact. The air quality at our location in Sydney is 7, which is good.

Lighting is an important aspect in any performance space. To minimize energy consumption, we plan on implementing LED lighting in all areas including stage lighting. Additionally, while the indoor lighting needs are what draw the most attention, we will be providing exterior lighting for sidewalks, parking lots, public transit zones and common areas.

For architectural style and materials, Sydney has a wide range of building styles. Our goal is to create a building that merges the ultra-modern and classical revival styles of architecture seen throughout Sydney. Historically, Sydney was known for building out of masonry due to the lack of trees available to build out of wood. Granite, marble, slate, and limestone were popular types of stone used for construction. Nowadays, it is possible to ship in any desired materials from other countries, but we would like to stick with materials that are readily available and sourced from Australia if possible. Some areas of the building we are working on lend themselves to having a large concentration of glass while other areas will be limited in the use of glass.

Our goal is to target wall structures that would be up to or exceeding current codes in terms of insulation. We would like to have a standard wall detail with varying veneer on the outside. There are various advantages to using a veneer as opposed to a solid masonry wall including being a lighter construction material, quicker to construct, and overall project cost.

For the structural system we are considering the use of steel, “plastic” concrete, and pre-stressed concrete. There are many considerations such as embodied energy, sustainability, and economical use

of material when it comes to the structural system. The sustainability of the structure should be able to last the lifetime of the building, be ready for expansion, and still have the potential to be recycled or reused in the future. The embodied energy in building materials can be high but can be offset with newer materials such as replacing some Portland cement with recycled plastic since cement is carbon intensive. We aim to use an economical member, using the least amount of material that still has the highest load carrying capacity. This could be something like using open web joists compared to a W-shape over a long span or using prestressed concrete to get a higher load carrying capacity.

(2) Structural Engineering Design

Project Description 1 ARE-4720

Green Mountain Structural

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The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has a design challenge where students embark on the “design of energy-efficient HVAC systems” for a pre-designed building, which is in Sydney, Australia for this year's challenge. Our team has not entered the ASHRAE design challenge since we are only designing the structure for the building in question. Our objective is to design a structure with low embodied energy that accommodates and compliments the function of the building.

We spent the first couple work sessions analyzing the building to understand what it will be used for and collecting data on Australia’s typical construction materials and methods to give us more understanding of structural materials, climate, loads, local codes, resilience, geography, and topography. Fortunately, Australia’s construction materials and methods are quite like what we have here in the northern United States. Australia’s climate does not fluctuate greatly. The temperature typically varies from 47°F to 80°F throughout the year and rarely goes below 42°F or above 90°F. We are carefully determining the loads that the building will encounter during its life, such as dead, live, rain, wind, and earthquake. We decided that there will not be a snow load because of Sydney, Australia’s climate, and no tsunamis or hurricanes because the site is 45 meters (about 148 feet) above sea level and is far enough inland, so the risk of damage due to tsunamis or hurricanes is low. We chose 2000 Elizabeth Street in Sydney, New South Wales, Australia as a location because it is a cultural hub within the city, just outside of the main downtown area. This is important for our building because we want it to be easily accessible to the public since it has a high occupancy, but not too far into the city where it is overshadowed by huge skyscrapers. We also do not want it in the more

residential areas where it would look and feel out of place. This location is perfectly balanced because it is in the transition area between inner city and residential neighborhoods, so it is not hidden nor hiding. The soil type has been determined to be ash field shale, which will serve as a solid base for the foundation. Figure 1 below shows a soil map of the site.

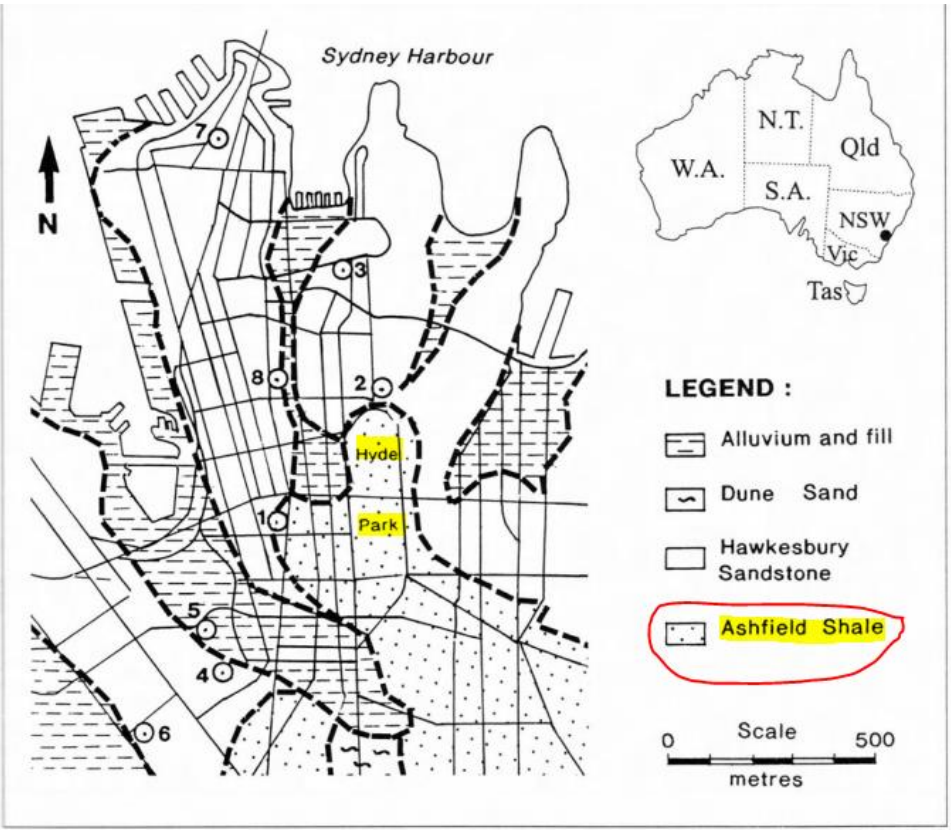

Figure 1: Soil Map (Lawrie, 1999)

Here in Vermont, USA, our building code is the 2015 International Building Code (2015 IBC) but in New South Wales, Australia they use National Construction Code 2019 (NCC 2019).

Bibliography

Lawrie, R. (1999, January 1). *Soil Chemical Properties at Historical Archaeology*. Retrieved from AUSTRALASIAN HISTORICAL ARCHAEOLOGY: https://asha.org.au/pdf/australasian_historical_archaeology/17_04_Lawrie.pdf