LA CRÊTE BIOMASS POWER FACILITY

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Abstract:

Architects and engineers are responsible for designing and building efficient structures with a minimum use of materials and energy. In this paper, the structural design of the La Crête Biomass Power Facility boiler island will be presented. The power plant is located in the city of La Crête, in Alberta, Canada. This plant is projected to power over 30,000 Canadian homes. The La Crête Biomass Power Facility will utilize well-established technology to provide communities with an efficient source of energy. The boiler island is an eight-storey building with a total height of 40 meters. The main structural challenge of this project is carrying a heavy, top-supported biomass boiler weighing 960,000 kg. A system of steel hanger rods is selected to suspend the eight-storey boiler and hold it in its place, while allowing for the thermal expansion of pressure parts..

As is typical in heavy industrial applications, steel construction is used for this project. The use of steel as a construction material breeds many advantages, such as light structural mass, low maintenance cost, ductility and durability, strength and long fatigue life.

One of the most important design considerations for steel structures supporting heavy mass is the dynamic response especially for post-disaster buildings. Finite Element Analysis software package STAAD.Pro V8i was used to evaluate mode frequencies, perform the dynamic analysis of the steel structure and design the steel members per NBCC 2010 and CAN/CSA-S16-09.

Keywords: steel structures; power plant; earthquake loads; wind loads; mode frequency.

1 INTRODUCTION

1.1 Project Description

The province of Alberta relies heavily on the burning of fossil fuels to generate power in its cities. With our planet experiencing a lot of changes in its climate it is necessary that everyone is placing an effort in reducing their environmental footprint. The La Crête Biomass Power Facility is designed to do just that. Its main function will be converting steam (generated through the burning of left over wood in the forest industry facilities) into electricity through traditional steam turbines and electric generators. The ash produced through this process makes for an excellent soil improvement on farming fields.

The power plant is designed to have an estimated life-span of 35 years, in which it will be operating 24 hours a day 7 days a week (except when maintenance is required). It is important to house this plant in a well-engineered steel structure and ensure that it will still be functional post-disasters.

1.2 Steel Structure Overview

The La Crête Biomass Power Facility boiler island is a 120 feet tall, eight-storey steel industrial building with a two-storey storage facility adjacent to the main structure. The building has the responsibility of housing a 2 000 000 lb biomass boiler and other related heavy equipment. When designing this structure two alternatives were taken into consideration, that of composite floors, and that of steel grating for floor design.

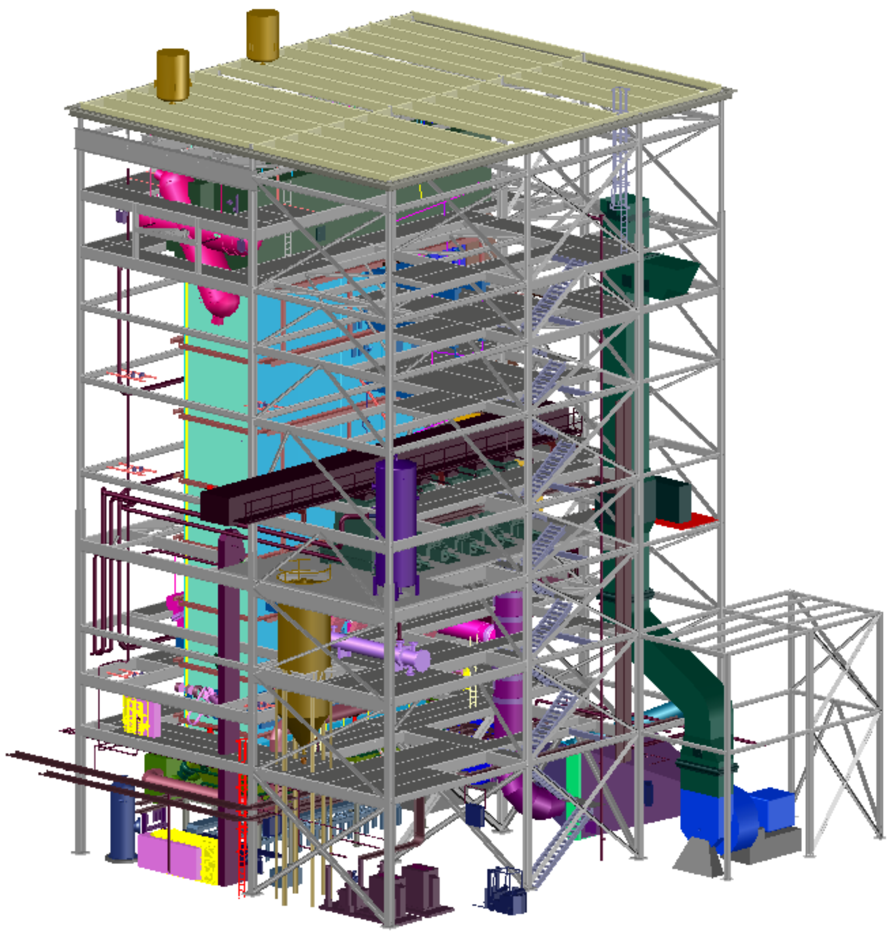


Figure 1: Boiler Island Structure

1.3 Scope of Work

The La Crête Biomass Power Facility plans to use wood waste to produce electricity. The plant will provide Alberta with a domestic, secure power source, while preserving the environment.

As the lead design consultants, it is our primary goal at Civil Adventure Solutions Ltd. to provide the most ideal, efficient, and serviceable building design achievable. Although we are not designing the working equipment within the facility, we as a design team are scheduled to consult upon the best building design to embrace the 41.5 megawatt biomass boiler and other applicable parameters.

The vendor's scope of work is as follows:

- ✓ Derivation of climatic loads per NBCC 2010
- ✓ Design of all floors
- ✓ Design of all beams
- ✓ Design of all columns
- ✓ Design of top deck (supporting the boiler)
- ✓ Design of roof
- ✓ Design of the horizontal diaphragms
- ✓ Design of the lateral resisting frames
- ✓ Design of stair tower
- ✓ Design of vertical bracing
- ✓ Design of base plates and anchor bolts
- ✓ Design of connections

When designing for the dead loads throughout the structure, the following table must be referenced.

Table 1: Weight of Equipment Housed in the Structure

Equipment	Weight (lb)	Weight (kN)	Weight (kg)	Floor Loaded
Sand Silo	176000.00	782.89	79,804.99	2
Economizer	478,800.00	2,129.81	217,105.91	2
Conveyor	82,700.00	367.87	37,499.29	3
Wood Feeders	124,500.00	553.8	56,453.01	3
Deaerator	87,500.00	389.22	39,675.74	3
Boiler & Steam Drum	2,000,000.00	8,896.44	906,874.92	top deck
Total	**2,949,500.00**	**13,120.03**	**1,337,413.86**	

2 ALTERNATIVES

2.1 Composite Floors Alternative

This alternative consists of a reinforced concrete slab placed on a series of corrugated steel sheets. Although this may result in a higher cost of labor, the benefits that arise from this alternative are many. Amongst them is the rigidity and strength of the design. It is versatile in the sense that it is compatible with all traditional structural systems. This design also allows for skid resistance in addition to its durability component. As concrete footings will be much larger than that of the first alternative, the weight of the building will increase significantly which will positively affect the resistance to seismic loadings.

Through the use of catalogues we determined to use a 166 mm concrete slab on corrugated sheets throughout all floors to minimize the cost and reduce errors in construction. We decided to select a 166 mm concrete slab depth (again including the 76 mm depth of the metal sheet), along with a sheet thickness of 1.52 mm (weighing 16 kg/m2), and secondary support spacing every 4 meters. The only floor which the spacing of the secondary beams and the corrugated sheet thickness is different is the third floor. In the third floor it was calculated that a sheet thickness of 0.76 mm and secondary beams placed every 1.6 meters.

2.2 Steel Grating Alternative

Through the implementation of our steel grating alternative, the La Crête Biomass Power Facility will benefit greatly. This design is composed of welded steel bars that are perpendicularly placed at equal intervals from each other. By the application of steel grating throughout the structure, with the exception of the third floor of the main building, the system will act as a stronger defense mechanism against all loading distributions. Such loadings include wind and seismic as these are laterally applied loads. The third floor, as to meet our client's needs, will be kept as a composite structure design. By using steel grating, a higher strength-to-weight ratio will be achieved. In addition to its high efficiency, the ease of installation and fabrication will permit for flexibility in replacement and deconstruction of members. This slip-resistant design allows for excellent drainage and free passing of any debris present in the building. Project construction phase will be shorter and thus allow savings in labor costs. Ultimately, steel grating consists of an efficient composition, safe design as it is corrosion resistant, sustainable background and long term serviceability.

For our alternative 1 design, the specified steel grating to be used will be 1-14" x 3/16" standard grating, type 19. Bearing bars will be 1-3/16" center to center and stock mats will be 3' x 24'. Weight of the steel grating is 8.87 lbs./sq.ft. All mats will be hot dipped galvanized to ensure for rust protection. Figure 2 depict the details of the steel grating to be used in the structure.

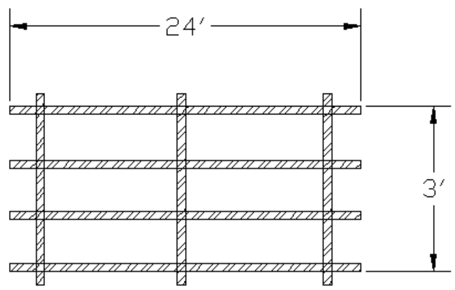


Figure 2: Steel Grating Dimensions

3 CHALLENGES

3.1 Column B-1

The column on gridline B-1 will have to be a 131 foot long column with several splice connections with no bracing on the north and south directions due to the eight storey boiler running through this path. The solution presented is implementing a truss system in mid-height of the building which would more reasonably be on the fourth floor. Figure 3 depicts the details of this system.

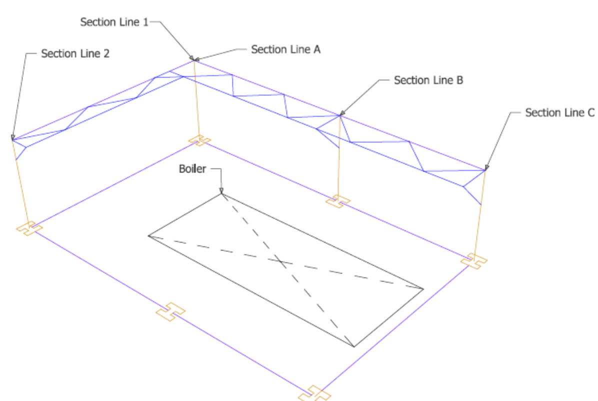


Figure 3: Fourth Floor Truss Placement

3.2 Economizer Framing

On approximately the second floor level of the structure, an economizer is located. This economizer is on a slightly higher elevation than the rest of the second floor (approximately one meter higher). The framing for this equipment was only a slight challenge due to the heavy loading and the fact that there needs to be an opening under the equipment in order for it to dispense its materials when in use.

It was decided to mount the economizer on top of two secondary W- shapes, with zero unbraced lengths on the top flanges, therefore only having to check local torsional buckling about the bottom flange.

Below is a drawing compiled on AutoCAD to showcase the framing for this machine:

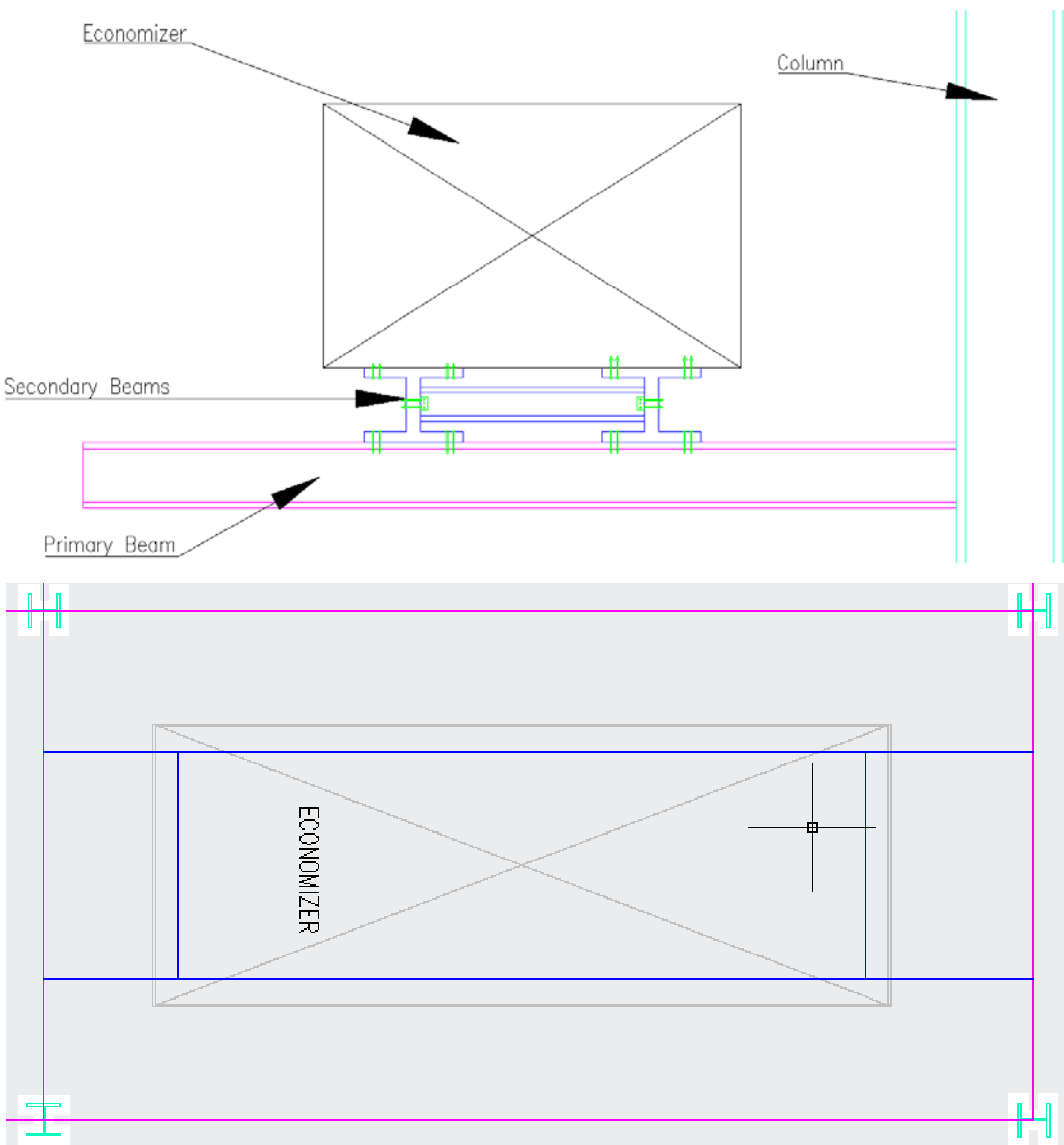


Figure 4: Economizer Framing Plan

3.3 Suspended Boiled Hanger Rods

The top deck of the building serves the purpose of hold and suspending the 2 000 000 lb mass boiler. As one can imagine, design and calculations must be very precise in order to achieve a safe and efficient installation as well as a structural system which offers a long-lasting service life. Figure 5 shows a perspective view of the top deck carrying the boiler. To that note, our design incorporates that arrangement of hanger rods which holds and suspends the boiler in its place. There will be a total of 74 hanger rods which will all be connected to a scheme of beams on one end and connected to the boiler of the other end.

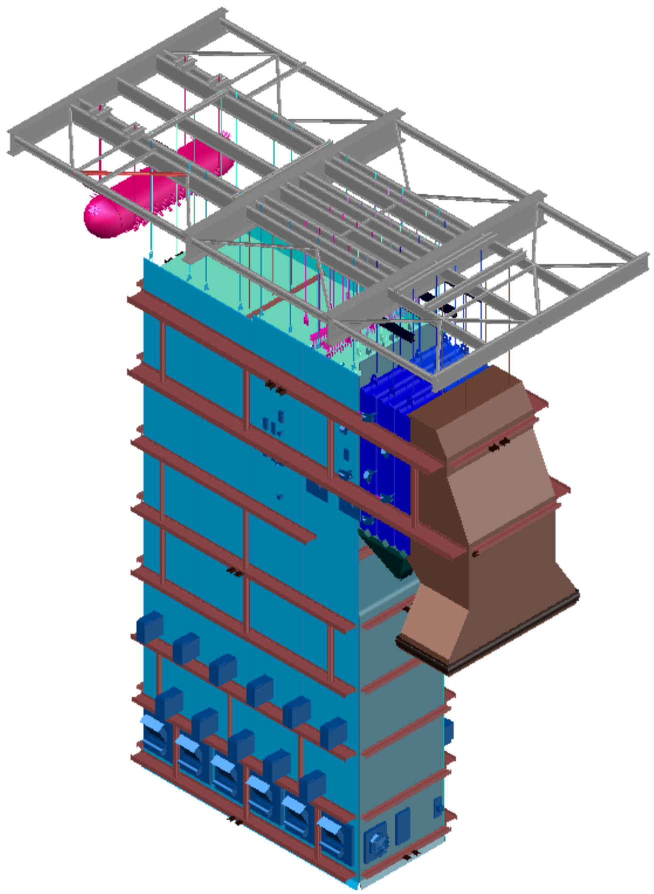


Figure 5: Top Deck and Boiler

4 CLIMATIC LOADS

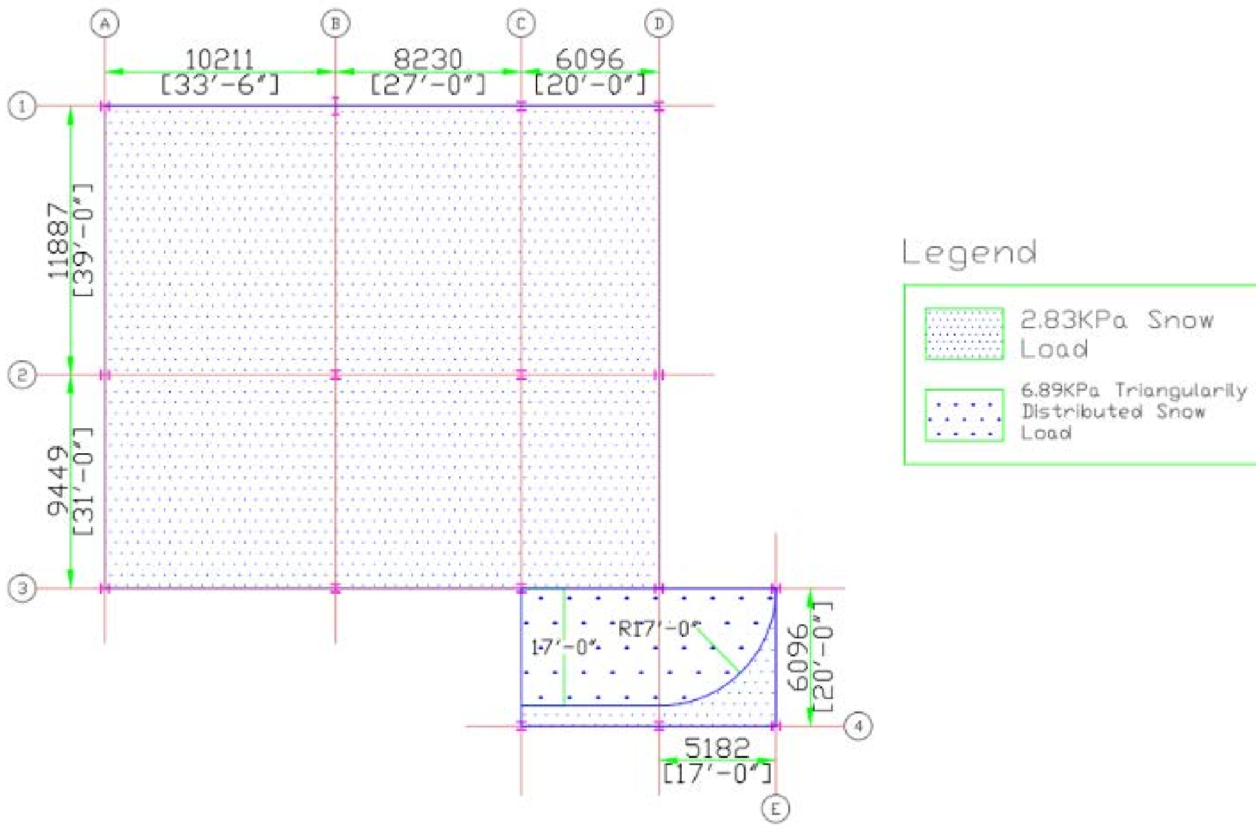
The climate information for La Crête was not readily available in the NBC, so the climate information from the town that was closest to La Crete, which was a town called Fairview was used for such calculations. Fairview is approximately 300km away from La Crête which is the most reasonable information to use to determining the climate loads for a structure in La Crête.

The climate loads consist of three different natures; snow, wind, and seismic loading. The snow loading fell into a gravity category loading due to it acting downwards. The wind and seismic loading were both categorized as lateral loadings. To design the building, the snow load needed to be determined as it is combined with the dead and live loads. The lateral load that needs to be considered on the building is the greater force of the wind or seismic force.

4.1 Snow Load

For the snow load, there are two different flat roofs to consider, the main building roof at an elevation of roughly 40m above ground level, and the lower storage building roof at roughly 12m above the ground level. By going through the NBC, we found several factors such as the importance, basic roof snow load, wind exposure, slope, and shape factors used to determine the loading on both buildings. As a result, the main building had a uniformly distributed snow load. For the storage building, due to both buildings being connected, there will be an additional accumulation of snow due to the drop of distance between the two buildings, in which there will be more snow on some parts of the storage building in certain locations.

Figure 7: Snow Load Distribution



4.2 Seismic Load

For the seismic load, due to clause 4.1.8.1 of the NBC, the seismic load was neglected in favour of the wind loads acting as the governing lateral loads. Northern Alberta has very low seismic activity which can be why it is neglected. To verify this, the seismic load was determined anyways. Site conditions are important to determine as geotechnical parameters, structural parameters, and the dead load of the structure can contribute to the seismic force. The spectral acceleration response periods were graphed to determine the fundamental period. Several factors were determined such as the importance, mode, and strength related factors from the NBCC. For a steel structure, the building turned out to have a very load response which helped clarify clause 4.1.8.1.

4.3 Wind Load

For the wind load, there were several heights on which the wind loads differ. The building was about 40m tall, and the wind loading changed every 6m, which meant there were seven different wind loads that varied throughout the height of the building. By going through the NBCC, several factors such as importance, exposure, gust factors and pressure coefficients were found. By putting all of the information into a table, the pressure along the building was determined. The information and factors determined the major & minor wind loads along with the wind pressure, suction, and uplift acting on the building.

Table 2: Wind Loads for Main Structural Members of eight Storey Building

Height (m)	I_w	C_g	C_e	E-W direction		N-S direction	
				C_{pnet}	P (kPa)	C_{pnet}	P (kPa)
0.00:6.00	1.3	2.0	0.632	1.8	1.035	1.6	0.920
6.00:12.00			0.726		1.189		1.057
12.00:18.00			0.787		1.289		1.146
18.00:24.00			0.834		1.366		1.214
24.00:30.00			0.872		1.428		1.270
30.00:36.00			0.904		1.481		1.316
36.00:39.827			0.923		1.512		1.344

Table 3: Wind Loads for Small Elements Including Cladding of eight Storey Building

Height (m)	I_w	C_g	C_e	E-W direction		N-S direction	
				C_{pnet}	P (kPa)	C_{pnet}	P (kPa)
0.00:6.00	1.3	2.5	0.632	1.8	0.961	1.6	0.855
6.00:12.00			0.726		1.104		0.981
12.00:18.00			0.787		1.197		1.064
18.00:24.00			0.834		1.269		1.128
24.00:30.00			0.872		1.326		1.179
30.00:36.00			0.904		1.375		1.222
36.00:39.827			0.923		1.404		1.248

5 COMPUTER MODELING

5.1 STAAD.Pro V8i

For the design analysis of this structure, the computer programs SAP 2000 and STAAD.Pro V8i were used. These programs allowed us to run different loading cases with special consideration to the climatic loads four our overall design of the foundation. Due to the fact that La Crête is placed in a low seismic activity region, performance against wind loads was our main concern. Wind loads were in accordance with NBCC 2005. Furthermore, our most optimized solution is to be found by STAAD.Pro V8i.

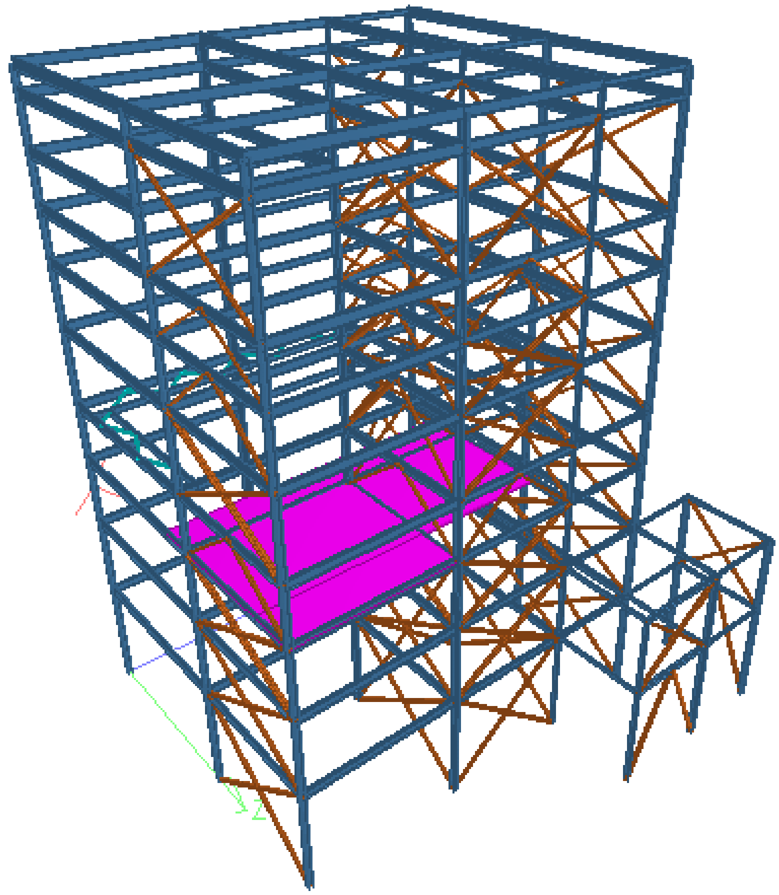


Figure 8: 3D STAAD model

6 CONCLUDING REMARKS

Based on all the information stated in the report, Civil Adventures Solutions Ltd. recommends to implement steel grating into the La Crête Biomass Power Facility Boiler Island. In comparison to concrete, the use of steel as a construction material include benefits such as lower maintenance cost, lighter structural mass, a better ductility, durability, and overall strength. After calculating all of our dead loads and climatic loads, STAAD.Pro V8i was used to evaluate mode frequencies, perform the dynamic analysis of our steel structure, and optimize the steel members while considering different load cases. Since the building is an industrial facility, aesthetics is not a major design factor. The table below shows a summary of the comparison between the two alternatives.

Table 4: Summary and Comparison of the two alternatives.

	Steel Grating	Composite Floors
Efficiency	• Areas where easy installation and fabrication are important • Areas where there are complex floor patterns and hard-to-fit areas • Situations that require a high strength-to-weight ratio	• Rigidity and strength of the steel/concrete design • Versatile: compatible with all traditional structural systems • Economical • Ability to take different shapes when forming
Safety	• Allows for slip resistance • Provides functional, durable installations	• Allows for skid resistance
Sustainability	• Virtually maintained free: high percentage of open areas allows for excellent drainage and free passing of debris • Allows for corrosion resistance	• Long Lasting when sealed and properly maintained
Serviceability	• Provides flexibility in replacement and deconstruction • Open area to allow passage of light, air, heat and sound between flooring levels	• Durable

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