by durability, attractive appearance and commitment to ecology, which makes them one of the key elements of modem and efficient building projects.

A comprehensive two-story timber structure design was undertaken to explore advanced engineered timber design techniques. The project initiated with an extensive review of structural timber properties and contemporary design methodologies. Specific architectural parameters were established for a rectangular building configuration measuring 32m x 24m with strategic grid layouts. CLT & LVL were chosen with regard to mechanical properties and sustainability of the engineered timber products. Specific architectural plans were created by AutoCAD for geometric modeling because of its accuracy. Structural analysis was performed through SAP 2000 software where three-dimensional modeling enabled comprehensive load simulation. Wind loads were also calculated with reference to the AS- ZS 1170 standards for wind speed with regional factors taken into consideration. The conditions of structural loading were considered according to the proposed classification. Drift and deflection analyses were used in order to assess structural health. Serviceability requirements were measured according to the existing Australian standards to achieve the best structural behavior and safety for various load conditions.

3.2.2 Objectives

The chief motto was to model 2-story timber structure that balances structural performance, functionality, & sustainability using advanced timber materials. Minor objectives were:

To boost structural efficiency by selecting high-performance timber materials.

To eliminate structural vulnerabilities through careful load analysis.

3.2.3 Nature of Works

I started a timber structure design project that was to combine architectural layout with structural engineering of high levels. I focused on new trends in timber materials and how they can be used in modem design. I created a layout plan for the two-storey building of the grid arrangements and dimensions. I chose primary structural materials that possessed improved mechanical characteristics. For architectural designing I employed CAD to prepare working plans and for structural designing SAP 2000 for three-dimensional design. Serviceability checks were also conducted for each structure and the results were compared with the drift & deflection analyses for the structural performance check. I analyzed various load combination and structural

2

3

3

and primarily served as lateral resisting elements. I decided on glass fa9ades for external walls to enhance the building's aesthetics while ensuring lightweight cladding.

Table 1: Illustrate of CLT panels (Radiata Pine Lamellas) characteristics

Structural Property

XGP1

Outer Lamellas

XGP2

Inner Lamellas

Modulus of Elasticity (parallel to the grain)

10,000 MPa

6,000 MPa

Bending Strength (parallel to the grain) Fb,o

17 MPa

10MPa

Compression Strength (parallel lo the grain) Fc.o

18 MPa

15 MPa

Compression Strength (perpendicular to the grain) Fc.oo

10 MPa

6 MPa

Tension Strength (parallel to the grain) F,.o

7.7 MPa

4.0 MPa

Shear Strength (parallel lo the grain) F,.o

2.6 MPa

2.1 MPa

Rolling Shear Strength (perpendicular to the grain) F,,oo

1.2 MPa

1.2 MPa

Shear Modulus (parallel lo the grain) Go

670MPa

400MPa

Rolling Shear Modulus G,

45Mpa

29Mpa

Mean Density p

500kg/ m3

475kg/ m3

Characteristic Density p

400 kg/ m3

380 kg/ m3

Available lamella sizes

85(w) X 42.5(t)

85(w) X 32.5(1)

85(w) X 30(1)

190(w) X 45(1)

140(w) X 35(1)

140(w) X 20(1)

Table 2: Depict of elsonpipe LVL 11 sections

Section Size (mm)

Mass (kg/ml

I,..(10'mm")

El, l10 Nmm')

Z,.(703mm'l

Of"bZ, lkNm)'

90x 45

2.3

2.7

30

61

2.1

115 x45

2.9

5.7

63

99

3.3

140 X 45

3,6

10,3

113

147

4,7

190 X 45

4.9

25.7

283

271

8.2

240x45

6.2

51.8

570

432

12.7

300 X 45

7.7

101.3

1114

675

19.1

360 X 45

9.2

175.0

1925

972

26.6

400 X 45

10 3

240 0

2640

1200

32.3

610 X 45

15.6

851.2

9363

2791

70.0

1220 X 45

31.3

6809.4

74904

11163

249.3

150 X 90

7.7

25.3

278

338

10.7

200 x90

10.3

60,0

660

600

18.1

240 X 90

12.3

103.7

1140

864

25.3

300 x90

15.4

202.5

2228

1350

38.1

360 X 90

185

349.9

3849

1944

53.2

400 x90

20.5

480.0

5280

2400

64.6

610 X 90

31.3

1702,4

18726

5582

139 9

1220 X 90

62.6

13618.9

149807

22326

498.5

3.3.3

I created the architectural ground floor plan by designing a rectangular layout of 32mx24m(figure2). I divided the plan into grids with 8m spacing along X-axis and 6m spacing along Y-axis. I marked the grid lines and labeled them horizontally as A to E and vertically as 1 to

5. I positioned columns at each grid intersection with dimensions of 400mmx45mm. I developed the column layout(figure3) by placing five built-up columns of 400mmx45mm at specified locations according to the design. I ensured the spacing between the columns aligned with the grid dimensions to maintain structural accuracy. I included all necessary labels to identify the components. I created the plinth floor plan(figure4) using the same grid layout. I added main beams with dimensions of 360mmx45mm and secondary beams of 200mmx90mm, ensuring they were correctly aligned and connected to the columns. I maintained the beam placements according to the span and load requirements. I designed the first-floor plan(figure5) & roof (figure6) similarly ensuring proper placement of the beams and columns for continuity. I created sections 1-1 and 5- 5(figure7) showing the height of the columns and beam connections. I detailed sections A-A and E-E(figure8) with a focus on the connections and structural alignment to ensure clarity.

A B C D E

.g,

.g,

:

.8,

g

32.00

Figure 2: Displaying GF architectural

Figure 3: Display oflayout for column

Figure 4: Illustrate of area for plinth floor

Figure 5: Showing FF layout

5

3

2

32,00

Roof floor plan

1

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Sttoelno4

SG.tht 1:100

Figure 6: Showing roof floor layout

Figure 7: Layout of at 1-1 & 5-5 section

Figure 8: Visualizing A-A & E-E and connection detail

1

1

1

1

1

1

A I 6 IC 10 I e

T T

>

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N +

Figure 9: Display of plan and 3D extruded

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LL\. ':::. L L:. L

Figure rn: Showing sections 1-1, 2-2, 4-4 & 5-5

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(3)

cf)

r ----

(2} ?)

( c)

T -

L :C:. fil fl:). L :C:.

Figure 11: Depict of3-3 section

LL

figure 12: Showcasing A-A and E-E with plain diagonal bracing

Figure 13: Display of 3D standard design

Figure 14: Imposing LL

/. t'\.

Figure 15: Imposing DL Table 3: Assignment of wind loading

Load Patter n

ExposeFr om

Angle

Wlndwa rd Cp

Leewa rd Cp

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Degre es

wind

Diaphragm s

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0.8

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SLS

Diaphragm

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0.8

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SLS-2

Diaphragm

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Diaphragm

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SLS-4

Diaphragm

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1

Figure 16: Distorted profile for l.2DL+ 1.SLL

Figure 17: Illustrate of BM for l.2DL+ 1.SLL

Table 4: Joint analysis

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nt

Output Case

01

02

03

Rl

R2

R3

m

m

m

Radians

Radians

Radians

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l.2DL+l.5 LL

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0.0000010

47

-4.616E- 07

-

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83

0.00020

7

-0.000293

2.093 -07

2

l.2DL+l.5 LL

0.0000027

28

5.241 -07

-

0.0001

54

0.00029

l

0.000443

-8.539E- 08

3

l.2DL+l.5 LL

3.971 -07

0.0000020

99

-

0.0001

66

-

0.00095

6

1.205 -07

-2.16 -11

4

l.2DL+l.5 LL

-

0.0000019

34

0.0000005

24

-

0.0001

54

0.00029

1

-0.000442

8.55 -08

5

l.2DL+l.5 LL

0.0000018

4

-4.617E- 07

-

0.0000

83

0.000\_0

7

0.000293

-2.089E- 07

6

l.2DL+l.5 LL

-

0.0000030

98

-

0.0000008

19

-

0.0001

7

-

0.00013

6

-0.000418

-6.501E- 07

7

1.2DL+l.5 LL

-

0.0000043

56

-4.263E- 17

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98

-4.406E- 17

-0.000646

-3.221E- 18

8

l.2DL+l.5

LL

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0.0000030

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0.0000008

19

-

0.0001

7

0.00013

6

-0.000418

6.501 -07

9

l.2DL+l.5 LL

0.0000018

4

4.617 -07

-

0.0000

83

-

0.00020

7

0.000293

2.089 -07

3.3.5

I observed that the storey drift(table5) for all levels of the structure was within the acceptable limits as per Clause 2.3.2 of AS3600-2018. I found that the deflection for the first storey was 0.47mm, with a storey drift of 0.47mm, and minimum acceptable limit was 9mm. I found that the deflection for the second storey was 0.63mm, with storey drift of0.16mm, & minimum acceptable limit was 9mm. I concluded that the model was accepted as per the storey drift check criteria. I validated the structural model by checking the roof rafter at grid 3 (A-C) in X(figurel8). I observed that the maximum deflection was 17.50mm, which was less than permissible limit of 20mm. I also

validated the beam at grid 3 (A-B) in X(figurel 9). I noticed that maximum deflection was 3.138mm, which was also within the limit of 20mm. I concluded that the provided sections were safe and satisfied serviceability requirements. I optimized the building sections through a trial-ancl error process. I finalized the optimized sections, which included 5 LVL 400x45 columns up to the third storey, 4 LVL 360x45 main beams in both directions, and LVL 140x45 bracing(table6). I ensured that all sections matched the design requirements. I deduced that building design was validated, optimized, and compliant with AS3600-2018 standards.

Table 5: Drift validation

Storey

Deflection

(mm)

Storey

Drift

(mm)

Minimum acceptable storey drift =

Storey heigh 500 (From Clause 2.3.2 ofAS3600-20l8) mm

Remarks

0

0

l

0.47

0.47

9

Model Accepted

2

0.63

0.16

9

Model Accepted

Dio)grl.lms fo1Ftamf Objt:ct 261 (4 roof raifte:r 240,:45) X

Case 1.5U. ..,.

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at8.1 1m P[)Siive in -2 drcciion

Shear\12

1-4.033.Ktl

1118,13$41 m

MomcntM3

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D!ifmchana

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Re541i io tuhat Unh Dooe

-20.3599 KN--m

at8.1 1m

Deflection (2-dirl

0.017501 m

111 3.6JOJ1 m

PtJi!Jliveln-20re-ctlon

Figure 18: Display of 3 (A-C) grid rafter validation in x

Diagram, for Frame Object 73 (4 main beam 360x4,)

Caae 1.2DL 1.5LL

ems Msj1;1r (V2 slid 1.13) v IfSilgle val.led vI

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O.ODJ1l8m

14. m

Posiive in --2 dSection

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Figure 19: Showing 3(A-B) beam at grid validation in x Table 6: Frame sections optimized

s.

Particulars

Assigned section

Designed section

bySAP2000

Columns

1

All columns upto third storey

5 LVL400 45

5 LVL 400 45

Beams

1

Main beams at X-di..i & Y-dir

4 LVL360 45

4 LVL 360 45

2

Seconda1y beam along Y-dir

2 LVL 200\*45

2 LVL 200\*45

Bracing frame

1

Bracing at y-direction

LVL 140\*45

LVL 140\*45

Roof sections

1

Roof Rafters

4 LVL240 45

4 LVL 240\*45

2

Purlins

LVL 115\*45

LVL 115\*45

3.4 Problem and Solution

I encountered the issue of a large deflection in the roof rafter grid 3 (A-C) in the positive X direction. I also found that the lower section of the part did not offer enough stiffness to regulate the deflection. I determined that the root was in load distribution during early modeling of the rafters. I checked with my supervisor about some assumptions that were made during the structural analysis. ext, I was advised to review the assigned section and think about a member of higher stiffness. Using the SAP2000 again, I reallocated the structure by placing a new section of 4 LVL 240x45 in place of the rafter. This I observed reduced the deflection to permissible level thereby conforming to the permissible limits. To validate, I reexamined and observed the results of the serviceability analysis. I managed to close the section and mark it as safe & compliant.

3.5 Creative Works

I recalled the model using SAP2000 and I substituted the rafter by one with better section of 4 LVL 240x45 for eliminating defections. I also rebalanced the loading conditions and fine-tuned the design to satisfy load carrying capacity and deflection constraints. On timber sections, I proactively chose stiffer material and sections for each member while at the same time consider serviceability limit in addition to the structural limit.

3.6 Project Management

I planned the overall structure and timeline of the project. I ensured that there was a clear vision of the project and laid down goals. I effectively co-ordinated the resources thait were needed in order to do the work. In order to make sure that I made proper progress on time, I came up with a time table. I ensured that the project followed a set time line in the following manner. To ensure that there was a record of the entire process, I kept record of everything throughout the project. I defined the ways of risk minimization. To the best of my abilities, I coordinated resources. I recorded progress reports on differing projects.. I revised and approved the project outputs. I compared the outcome of the project to the goals set at the beginning of the project. I was also keen on proper arrangement of all project related fi!es & documents. I met with supervisor often to discuss project issues and milestones.

3.7 Codes

I adopted AS 1720.1-2010 for timber structural design & applied AS 1170.2 - Part 2 for wind load calculations.

3.8 Summary

3.8.1

A comprehensive two-story timber structure design was successfully accomplished through systematic engineering approaches. Fundamental research on timber materials was initially conducted. Advanced engineerecl timber materials like CLT & LVL were extensively investigated. Architectural planning was meticulously executed using precise grid configurations. Detailed architectural and structural layouts were developed in AutoCAD. Structural modeling was performed using SAP 2000 software. Comprehensive load analyses were undertaken including fire safety considerations. Structural performance was rigorously validated through drift checks and deflection measurements. Optimization of structural sections was achieved through iterative design processes. The final design demonstrated compliance with structural standards. Structural efficiency was ensured through careful material selection and computational analysis. High performance timber materials were chosen, compared, and approved using SAP 2000 modeling. Structural weaknesses were evaluated through load analysis, load factors & combinations, and serviceability criteria.

3.8.2

I ensured that I \had good time management by arranging the project appropriately. I improved decision making by allocating resources. I honecl problem-resolving skills by solving problems & got to learn risk management skills.