PLANNING, ANALYSIS AND DESIGN OF TIMBER RESIDENTIAL STRUCTURE USING AUSTRALIAN STANDARDS

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ABSTRACT

Timber is increasingly used in residential construction due to its sustainability, lightweight nature, and ease of construction. However, timber structures are significantly affected by environmental factors such as wind loads and fire exposure, which must be considered during design.

This project focuses on the planning, analysis, and design of a timber residential structure with emphasis on wind resistance and fire performance. The structural layout is developed and suitable materials such as machine graded pine are selected. The analysis is carried out using SAFER software, and loads including dead load, live load, and wind load are determined.

Wind classification and terrain conditions are considered to evaluate wind effects, while fire performance is assessed using Bushfire Attack Levels (BAL). Structural members are designed to satisfy strength, stability, and serviceability requirements.

The study concludes that timber structures can perform efficiently under environmental loads when proper design methods are adopted, making them a reliable and sustainable option for residential construction.

Keywords:

Timber structures, Residential building, Wind load, Fire performance, Bushfire Attack Level (BAL), Structural analysis, Load calculation, Wind classification, Terrain category, Bracing systems, Beam design, Roof truss, Sustainable construction.

INTRODUCTION

1. GENERAL

Construction plays a vital role in modern infrastructure, where selecting suitable materials is important for safety, durability, and sustainability. In recent years, the use of timber in residential buildings has increased due to growing awareness of environmentally friendly construction.

Timber is preferred for its high strength-to-weight ratio, ease of construction, and availability. It allows faster construction and reduces overall structural weight compared to materials like concrete and steel. However, timber structures are affected by environmental factors such as wind and fire. Due to their lightweight nature, they are more vulnerable to wind uplifts and lateral forces. Fire safety is also a concern, although timber behaves predictably by forming a protective char layer.

To address these challenges, Australian Standards are used for design, load calculation, wind resistance, and fire performance. This project focuses on the planning, analysis, and design of a timber residential structure considering these factors.

1.2 SOFTWARE

The structural modeling, analysis, and detailing of the timber residential structure were carried out using SAFER software. This software is specifically used for timber framing design and supports the application of Australian Standards.

1.2.1 The software was used for the following purposes:

1. Preparation of structural layouts including wall framing and openings.
2. Modelling of beams, rafters, and roof trusses.
3. Application of loads such as dead load, live load, and wind load.
4. Analysis of structural behaviour and load distribution.
5. Generation of 3D models for visualization
6. Detailing of structural components and connections

1.3 MATERIAL USED

The primary material used in this project is structural timber, specifically machine graded pine such as MGP10 and MGP12. These grades are selected due to their adequate strength, availability, and suitability for residential construction.

Timber also shows predictable performance under fire conditions. When exposed to fire, it forms a char layer that protects the inner core, thereby maintaining load-carrying capacity for a certain duration.

1.3.1 SECONDARY MATERIALS

1. Fasteners and Connectors

   Nails, screws, and metal connectors are used to join timber members. These components are essential for transferring loads between structural elements and ensuring overall structural integrity.

2. Bracing Materials

   Plywood or oriented strand board (OSB) panels are used as bracing elements in walls. These materials provide resistance against lateral loads such as wind and improve the stability of the structure.

3. Roofing Materials

   Lightweight roofing materials are used to reduce the dead load acting on the structure. This helps in minimizing wind uplift effects and improves the overall efficiency of the design.

4. Fire Protection Materials

   Fire-resistant materials such as gypsum boards and protective cladding are used to enhance the fire performance of the structure. These materials delay fire penetration and reduce direct exposure of timber members.

1.4 CODES AND STANDARDS

- **Timber Design**

  AS 1720.1 – Timber Structures is used for the design of structural timber members. It provides guidelines for checking bending, shear, compression, and deflection, ensuring both strength and serviceability requirements are satisfied.

- **Residential Timber Framing**

AS 1684 – Residential Timber-Framed Construction is used for planning and detailing timber framing systems. It includes provisions for wall framing, roof structures, and bracing requirements, ensuring practical and safe construction.

- **Dead Load and Live Load**

AS 1170.1 – Structural Design Actions (Permanent and Imposed Loads) is used to determine dead loads such as self-weight and live loads due to occupancy. This ensures realistic load estimation for structural analysis.

- **Wind Load**

AS 1170.2 – Structural Design Actions (Wind Actions) is used to calculate wind loads acting on the structure. It includes provisions for wind speed, terrain category, and wind classification such as N1 and N2. This is essential for ensuring stability against lateral and uplift forces.

- **Fire Resistance and Bushfire Design**

AS 1720.4 – Fire Resistance of Timber Structures is used to evaluate the fire performance of timber members based on charring behavior.

AS 3959 – Construction of Buildings in Bushfire-Prone Areas is used for determining Bushfire Attack Levels (BAL 12.5, BAL 19, BAL 25) and specifying fire-resistant construction requirements.

1.5 WIND CLASSIFICATION

Wind classification is considered in this project to understand how wind affects the timber residential structure. Since timber buildings are lightweight, they are more vulnerable to wind forces such as uplift and lateral loads. If wind effects Are not properly considered, it may lead to structural instability or failure of roof and wall components.

As per Australian Standards, wind load is determined based on wind region and terrain category. These factors help in estimating the wind pressure acting on the building and are important for safe design.

1.5.1 Wind Regions

- N1 – Represents low wind regions, generally used for normal residential areas with lower wind speeds.
- N2 – Represents moderate wind regions with higher wind pressure compared to N1, requiring stronger structural design.

1.5.2 Terrain Categories

- Category 1 (CAT 1)

Open areas such as coastal regions or flat land with very few obstructions, resulting in higher wind speed.

- Category 2 (CAT 2)

Suburban areas with some buildings and trees, causing moderate reduction in wind speed.

- Category 3 (CAT 3) Densely built areas with many obstructions, where wind speed is reduced significantly.

LITERATURE REVIEW

2.1 GENERAL

The literature review presents an overview of previous studies related to the design and behaviour of timber structures used in residential buildings. It highlights various research findings on structural performance under loads such as dead load, live load, wind, and fire conditions. By analysing earlier works, the review identifies important factors affecting timber structures, including bracing systems, connection behaviour, and load distribution.

This study also helps in understanding the response of timber structures to environmental effects and the importance of proper design methods. It provides a clear idea about the advantages and limitations of timber in construction. Overall, the literature review forms a strong foundation for carrying out the present project on planning, analysis, and design of a timber residential structure.

G.C. Foliente (2000)

This study focuses on the structural reliability of timber buildings under extreme loading conditions such as wind and seismic effects. The author explains the importance of limit state design in ensuring safety and performance. The research highlights how timber structures respond to dynamic loads and emphasize the need for proper design methods to improve structural stability. It also discusses failure modes and the importance of considering real-life loading scenarios in design.

G.N. Boughton (2013)

This work provides detailed guidance on timber design principles, including bending, shear, and compression behaviour of timber members. The study explains how timber elements should be designed to meet strength and serviceability requirements. It also highlights the importance of selecting appropriate material grades and ensuring proper structural detailing. The research is useful in understanding how timber members perform under different loading conditions in residential construction.

K. Crews & G. Doudak (2015)

This study investigates the stability and load-sharing behaviour of timber structures. It emphasizes the importance of bracing systems in resisting lateral loads such as wind. The authors explain how improper bracing can lead to structural instability. The research also discusses load distribution between different members and highlights the role of connections in maintaining overall stability. It provides useful insights into designing safer timber structures.

R. Lambe & J. Murray (2014)

This paper focuses on the buckling behaviours of timber compression members. It explains how the slenderness ratio affects the load-carrying capacity of timber columns. The study highlights the importance of proper sizing and support conditions to prevent failure. It also discusses how different boundary conditions influence stability. This research is important for understanding column design in timber structures.

R.L. McGavin et al. (2019)

This study reviews the use of engineered timber in modern construction. It highlights the advantages of timber such as improved strength, reduced weight, and better performance. The authors discuss how engineered products can overcome limitations of traditional timber. The research also focuses on structural stability and the use of timber in larger buildings, showing its potential in future construction.

L.M. Ottenhaus& K. Crews (2021)

This paper examines the behaviour of timber connections under different loading conditions. It highlights that connections play a major role in overall structural performance. The study explains how joint stiffness affects load distribution and stability. It also discusses different types of connections and their performance. The findings emphasize the importance of proper connection design in timber structures.

Standards Australia Committee BD-003 (2016)

This work focuses on the development of timber design guidelines, including stability checks and buckling considerations. It provides procedures for designing timber members safely. The study highlights the importance of following standard design methods to avoid structural failure. It also explains the role of design codes in ensuring consistency and safety in construction practices.

A. Amirsardari et al. (2022)

This research analyses the behaviour of timber frames under lateral loads such as wind. It emphasizes the importance of ductile connections in improving structural performance. The study shows how proper detailing can enhance energy absorption and reduce damage. It also highlights the role of bracing systems in maintaining stability during loading conditions.

C.J.L. Cowled & K. Crews (2020)

This study investigates the effect of environmental conditions on timber connections. It explains how moisture, temperature, and external factors affect durability and performance. The authors highlight the importance of considering long-term behaviours in design. The research provides insights into improving the lifespan and reliability of timber structures.

S. Soleimani & K. Crews (2023)

This paper focuses on the robustness of multi-storey timber structures. It explains how load redistribution helps prevent structural failure. The study highlights the importance of designing for unexpected loading conditions. It also discusses how proper structural detailing can improve safety and performance. This research is useful for understanding advanced timber construction techniques.

APPLICATION OF AI IN FIRE RISK ASSESSMENT

3.1 General

In this project, an AI-based approach is considered to assess fire risk in timber residential structures. Since timber is a combustible material, it is important to evaluate fire exposure conditions during the design stage. The AI concept helps in analysing different factors that influence fire behaviour and provides suitable recommendations for improving safety. This approach supports better decision-making by identifying risk levels and suggesting appropriate protective measures for timber structures.

3.2 AI-Based Fire Risk Assessment

The AI-based fire risk assessment system is used to evaluate the level of fire risk based on selected input conditions. It processes the input data and provides outputs that help improve the fire safety of the structure.

3.2.1 Input Parameters

1. Bushfire Attack Level (BAL 12.5, 19, 25)
2. Type and grade of timber material
3. Presence of fire-resistant cladding
4. Building location and surrounding conditions
5. Exposure to fire-prone environment

3.2.2 Output Parameters

6. Fire risk level (Low / Moderate / High)
7. Recommended protective materials
8. Suggested design improvements
9. Safety measures for fire resistance

3.3 Working Principle

The system works by comparing the given input parameters with predefined fire-related conditions. Based on the input data, the AI evaluates the level of fire exposure and predicts its impact on timber members. It then provides suitable recommendations such as improving protective layers or modifying design details. This helps in enhancing the fire resistance of the structure.

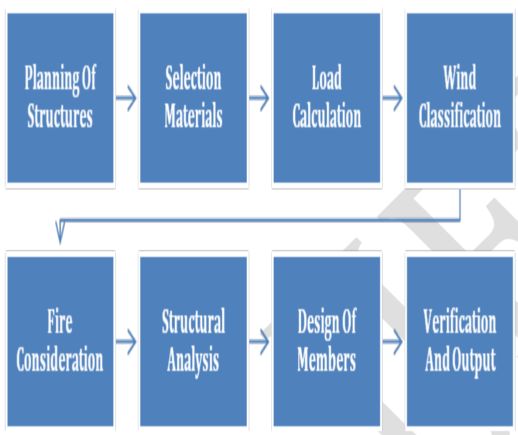
3.4 Advantages

10. Provides quick fire risk evaluation
11. Helps in selecting appropriate fire protection methods
12. Improves structural safety under fire conditions
13. Supports better design decisions

METHODOLOGY

4.1 GENERAL

The methodology adopted in this project involves the planning, analysis, and design of a timber residential structure in a systematic manner. The process begins with planning the building layout and selecting suitable materials. It is followed by the calculation of loads such as dead load, live load, and wind load. Wind classification and fire considerations are also included to understand their effects on the structure. Structural analysis is then carried out to determine forces acting on members. Finally, the design of timber elements is completed to ensure safety, stability, and proper structural performance.



4.1 Methodology

TRUNCATED TRUSS

5.1Truncated Truss

- A Truncated Truss is a modified roof truss where the top portion (apex) is “cut off” or flattened instead of forming a sharp peak.
- Commonly used in hip roofs and modern residential design
- Creates a flat or shortened top section instead of a full triangular shape

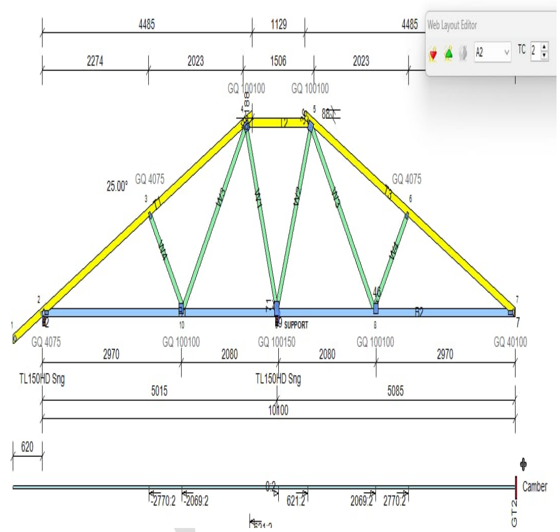


Fig 5.1 Truncated Truss

5.1Support

A support is indicated, showing that the truss receives structural support from the interior load-bearing wall (LBW).

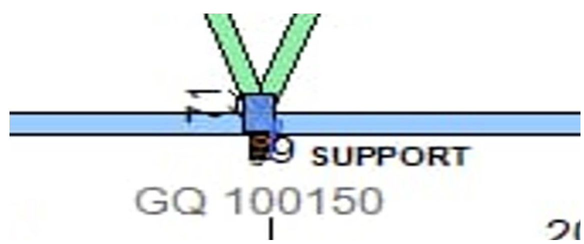
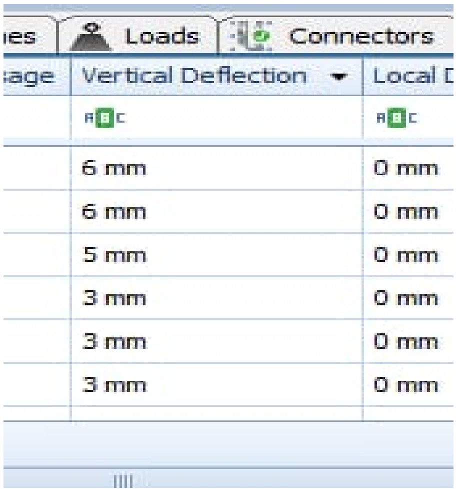


Fig5.2 Support

5.1Deflection of Truncated Truss

The truss is considered safe because its deflection is within the allowable limits. The permitted deflection is 9 mm for the top chord and 7 mm for the bottom chord. In this case, both the top and bottom chords have a deflection of only 6 mm, which is below the allowable values. Therefore, the truss is safe and performs satisfactorily.



...age	Vertical Deflection	Local D...
	6 mm	0 mm
	6 mm	0 mm
	5 mm	0 mm
	3 mm	0 mm
	3 mm	0 mm
	3 mm	0 mm

Fig5.3 Deflection of Truncated Truss

AC TRUSS

6.1 AC Truss in Timber Roof Construction

It is basically a standard triangular truss used in houses, designed to carry both roof loads and ceiling loads in its TOP CHORD member.

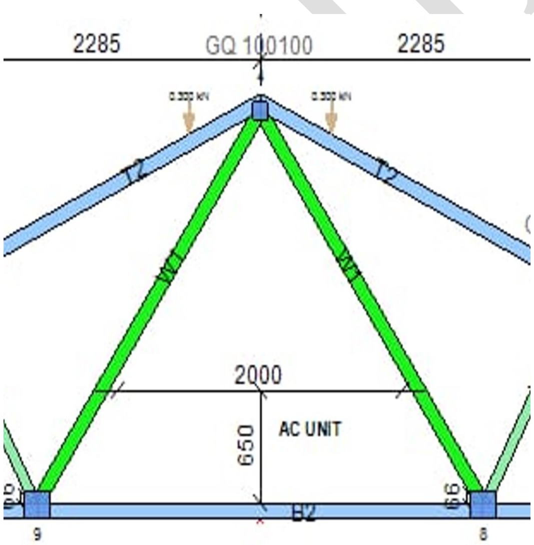


Fig6.1 AC Truss in Timber Roof Construction

As in the above shown image you can able to find out a two arrow marks is placed on the top chord of the truss. The arrow is nothing but the ac loads because as per the plan specifications the AC is to be placed on the TOP CHORD of the member.

The below mentioned dimensions (2000mm in length and 650mm width) is nothing but sizes of the AC.

As per the standards we should allow the correct space capacity to fit the AC without creating any error

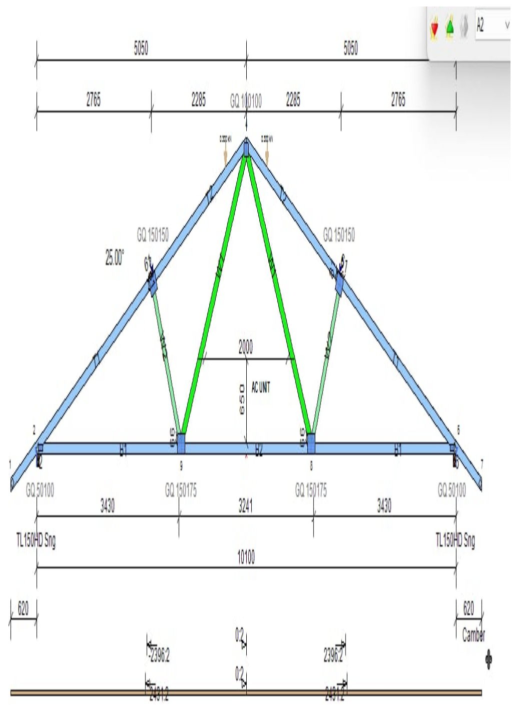


Fig6.2 AC Truss in Timber Roof Construction

6.2 Deflection

The truss is considered safe because its deflection is within the allowable limits. The permitted deflection is 9 mm for the top chord and 7 mm for the bottom chord. In this case, the top chord shows a deflection of 8 mm and the bottom chord shows 7 mm. Since these values are within the permitted limits, the truss is safe and performs satisfactorily.

Planes	Loads	Connectors
lessage	Vertical Deflection	Local De
	8 mm	0 mm
	7 mm	0 mm
	6 mm	0 mm
	5 mm	0 mm
	4 mm	0 mm
	4 mm	0 mm

Fig6.3 Deflection

GRIDER TRUSS-1

7.1Grider Truss

A girder truss is a strong primary truss designed to support smaller trusses, such as common or jack trusses. It acts like a main beam in the roof system, carrying and distributing loads. This type of truss is referred to as a Half-Truncated Girder Truss (HTGT1).

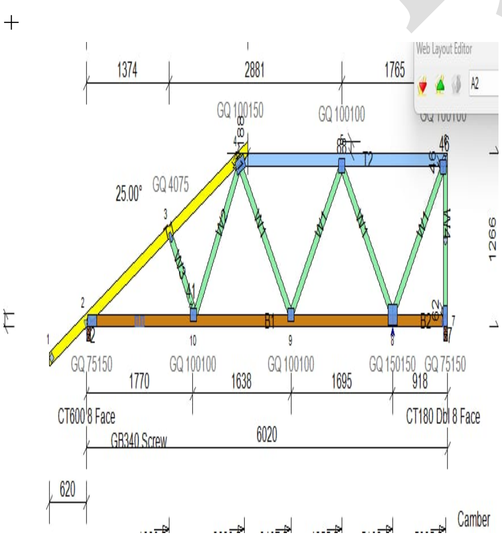


Fig7.1 Grider Truss

Purpose:

- Carries heavy loads from other trusses
- Used where roof layout is complex (hip roofs, valleys)
- Reduces the need for extra internal supports

7.2 GB340 SCREW

A GB340 screw is a structural timber screw used in Australian timber construction for heavy-duty connections.

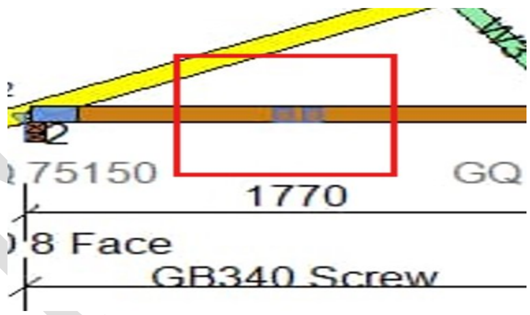


Fig7.2 GB340 SCREW

7.2 Deflection

The truss is considered safe because its deflection is within the allowable limits. The permitted deflection is 9 mm for the top chord and 7 mm for the bottom chord. In this case, the top chord shows a deflection of 6 mm and the bottom chord shows 5 mm. Since both values are less than the permitted limits, the truss is safe and performs satisfactorily.

anes	Loads	Connec
ssage	Vertical Deflection	L
	6 mm	C
	5 mm	C
	4 mm	C
	4 mm	C
	3 mm	C
	3 mm	C

Fig-7.3 Deflection

GRIDER TRUSS 2

8.1 GRIDER TRUSS 2

A girder truss is a strong primary truss designed to support smaller trusses, such as common or jack trusses. It acts like a main beam in the roof system, carrying and distributing loads. This type of truss is referred to as a Half-Truncated Girder Truss (HTGT2).

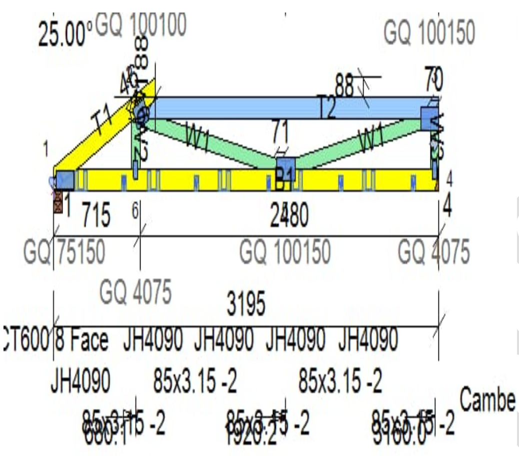


Fig8.1 Grider Truss-1

Purpose:

- Carries heavy loads from other trusses
- Used where roof layout is complex (hip roofs, valleys)
- Reduces the need for extra internal supports

8.2 JH4090 SCREWS

A joist hanger is a metal connector used to support and hold a timber member, such as a joist or a secondary truss, to a girder truss. In simple terms, it acts like a seat or bracket that safely holds the timber in place.

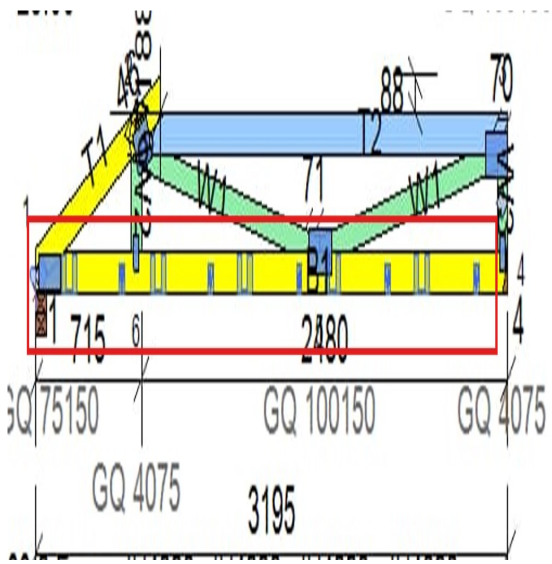


Fig8.2 JH4090 SCREWS

8.3 Deflection

The truss is considered safe because its deflection is within the allowable limits. The permitted deflection is 9 mm for the top chord and 7 mm for the bottom chord. In this case, both the top and bottom chords show a deflection of 7 mm. Since these values are within the permitted limits, the truss is safe and performs satisfactorily.

lessage	Vertical Deflection	Loc
	7 mm	0 m
	7 mm	0 m
	6 mm	0 m
	5 mm	0 m
	5 mm	0 m
	4 mm	0 m

Fig-8.3 Deflection

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FULL TRUNCATED TRUSS

9.1 Full Truncated Truss

A fully truncated truss is a type of roof truss in which the top (apex) is completely cut off and made flat. Instead of having a pointed triangular shape, it features a flat top section across the entire upper portion.

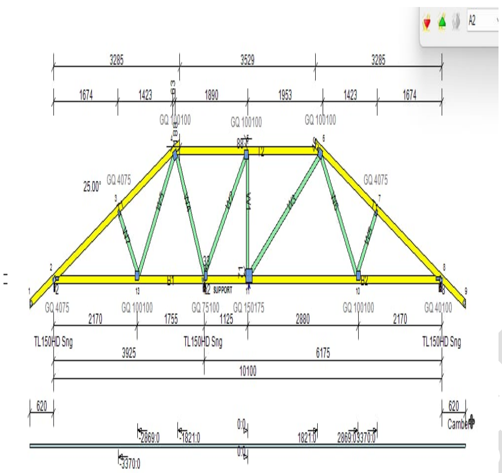


Fig9.1 Full Truncated truss

a) Mainly in hip roof systems
b) Common in Australian timber houses
c) Used at the centre/top portion of hip roof layouts

9.2 Support

A support is indicated, showing that the truss receives support from the interior load-bearing wall (LBW).

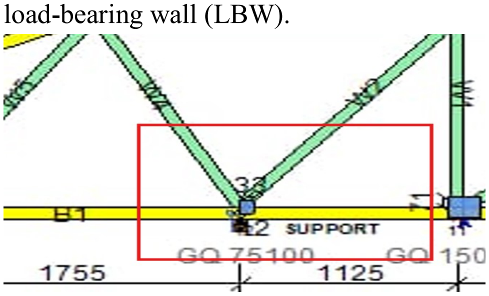
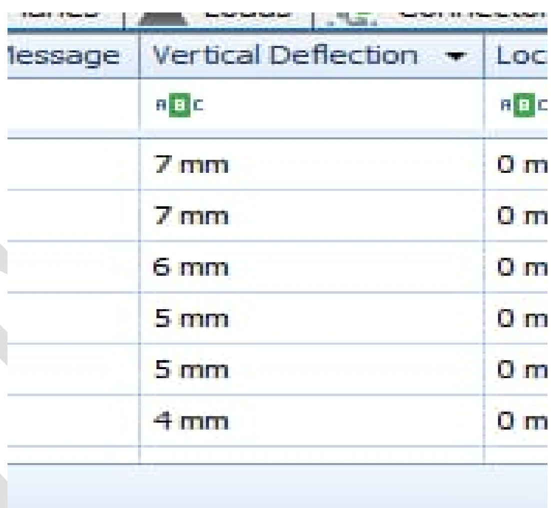


Fig 9.2 Support

9.3 Deflection

The truss is considered safe because its deflection is within the allowable limits. The permitted deflection is 9 mm for the top chord and 7 mm for the bottom chord. In this case, both the top and bottom chords show a deflection of 7 mm, which is within the allowable limits. Therefore, the truss is safe and performs satisfactorily.



lessage	Vertical Deflection	Loc
	7 mm	0 m
	7 mm	0 m
	6 mm	0 m
	5 mm	0 m
	5 mm	0 m
	4 mm	0 m

Fig 9.3 Deflection

HALF SADDLE&TRUNCATED SADDLE

10.1 HALF SADDLE

A half saddle is a supporting timber member fixed on one side of a truss or beam to help carry another member. It acts like a small support block provided on one side to hold a timber member in place. In this arrangement, the top chord member is sized at 90 × 35 F5, as it is used to connect to the girder and requires higher strength. The remaining members are 70 × 35 F5, which are sufficient for their role and help in reducing overall cost.

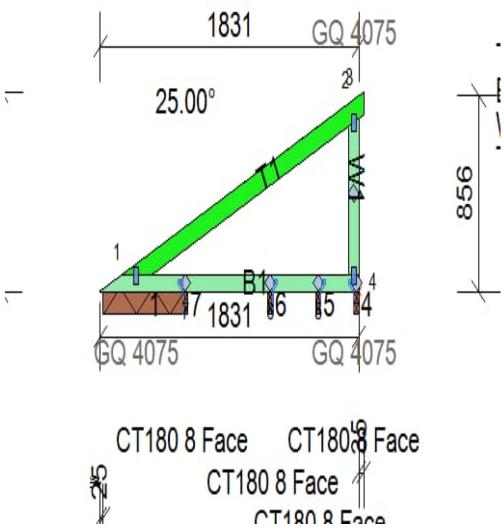


FIG 10.1 HALF SADDLE

10.2 TRUNCATED SADDLE

A truncated saddle is a supporting timber block or seat that is cut and shaped to match the slope or profile of a truncated truss. It acts as a support piece that helps to properly seat and hold members in position within a truncated truss system.

It is commonly used in truncated or fully truncated trusses, especially at the connections of jack trusses or rafters to a girder truss. Truncated saddles are widely used in hip roof construction to ensure proper load transfer and stability.

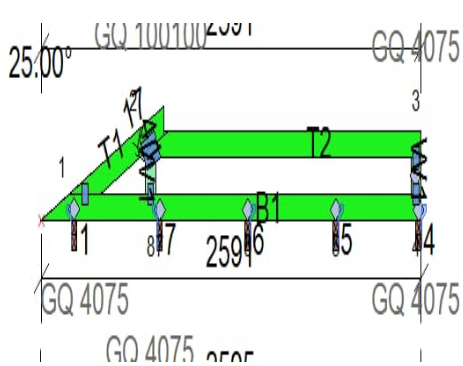


FIG 10.2 TRUNCATED SADDLE

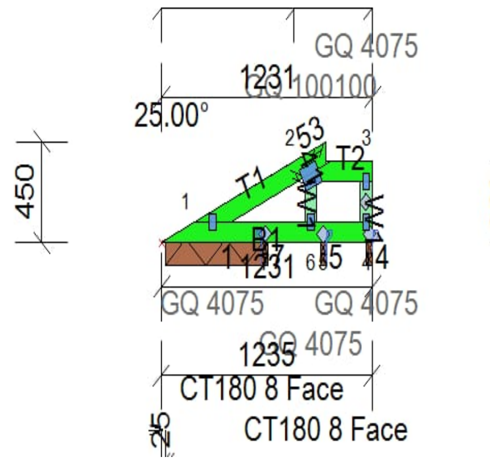


FIG 10.3 TRUNCATED SADDLE

Purpose:

a) To provide proper seating for sloping members
b) To ensure correct alignment of truss components
c) To improve load transfer efficiency
d) To prevent slippage of members

FLY RAFTERS

11.1 FLY RAFTERS

Fly rafters are inclined timber members placed along the edge of a roof, usually extending beyond the main truss. They act as outer rafters that form the roof overhang, also known as the eaves.

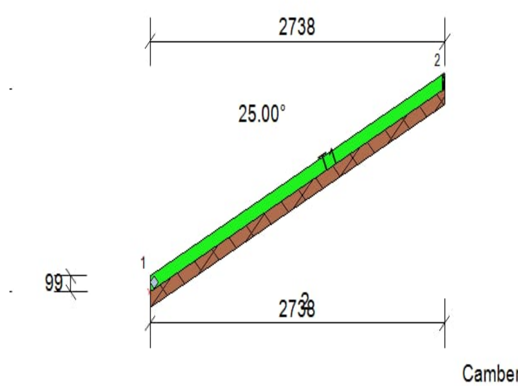


FIG 11.1 FLY RAFTERS

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11.2 SUPPORT

In the image, the support is indicated as grounded. This is because the fly rafter is used to support saddles and does not have a direct support connection. In such cases, it is considered as a grounded load. When a grounded load is applied, the load is distributed evenly to all sides of the rafter.

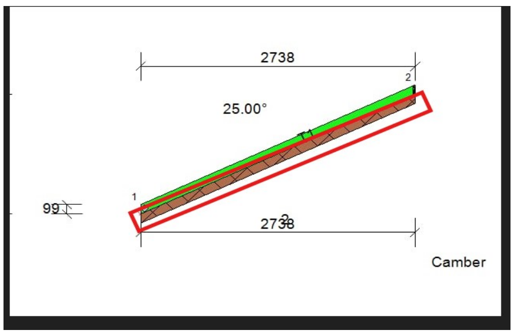

FIG 11.2 SUPPORT

RAFTERS

12.1 RAFTERS

Rafters are sloping timber members that run from the ridge (top) down to the wall or support. They act as inclined beams that support the roof covering. Rafters play an important role in the truss system by forming the roof slope (pitch), supporting roof materials such as tiles or sheets, and transferring loads to the truss or supporting walls.

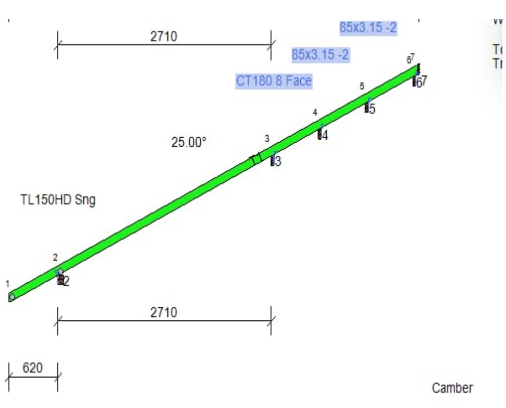

Fig 12.1 Rafter

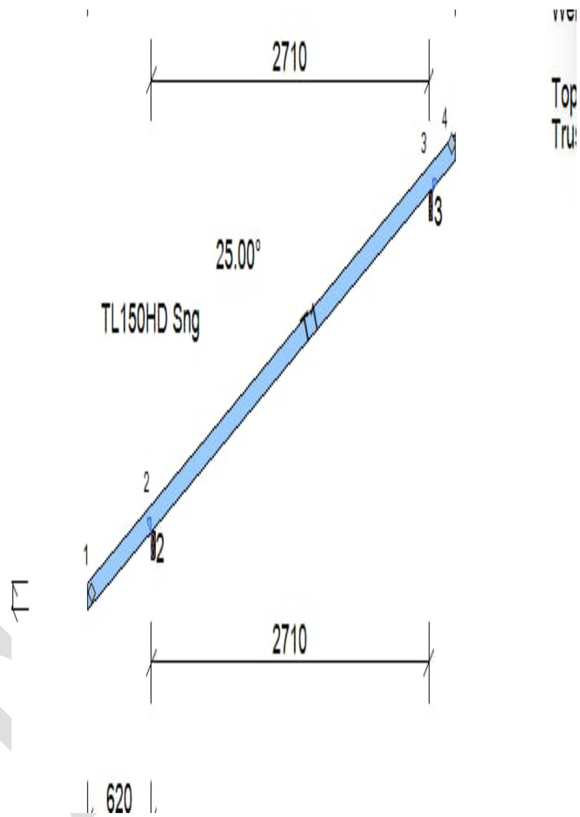

Fig 12.2 Rafter

This member is also a rafter, but it is provided in **P12 grade**. The higher grade is selected to meet increased load requirements, as the member strength is determined based on the load conditions.

FULL HIPS & SMALL FULL HIP & HALF HIPS

13.1 FULL HIPS

The triangular formation shown in the image is called a full hip. This type of structure helps to cover the entire hip of the house. It is designed to work within standard girder spacing, typically ranging from 2580 mm to 2740 mm. The full hip can be safely used only within this range; if the girder spacing exceeds 2740 mm, the structure may become weak and could fail.

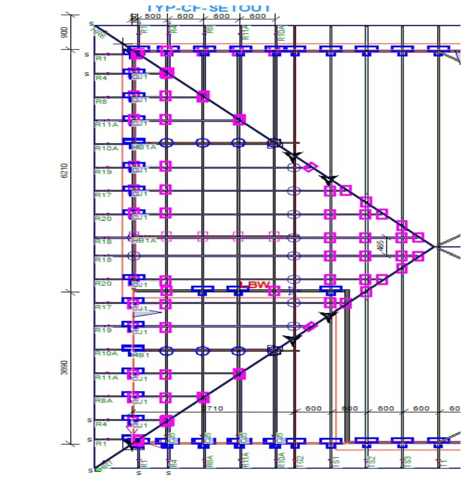

Fig 13.1 Full Hips

13.2 SMALL FULL HIPS

The small full hip is similar to a standard full hip, but it has a smaller span. It is designed with different hip spacing, typically ranging from 1765 mm to 2365 mm. In some cases, the girder spacing may be slightly increased beyond 2365 mm to prevent overlapping of structural members.

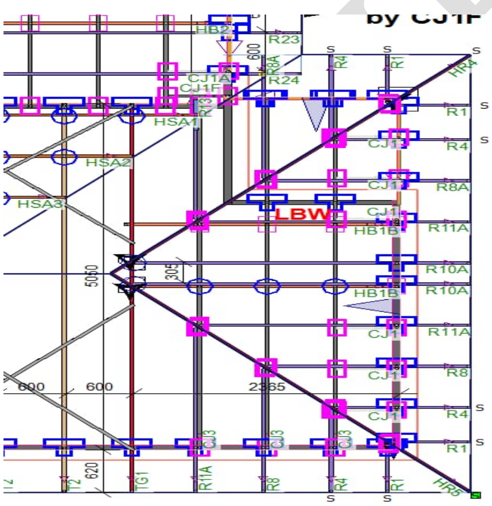

Fig 13.2 Small Full Hips

13.3 HALF HIPS

The **half hip** is similar to a full hip, but it is used only in specific areas. It helps to complete or fill parts of a full hip where required. Half hips also have similar girder spacing as full hips.

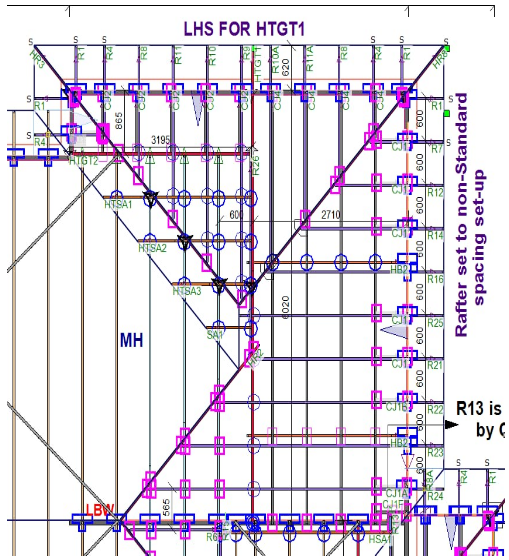

Fig 13.3 Half Hips

Usually, a house includes one full hip, one amalgamation hip, one small hip, and two half hips. Most timber roof structures are formed using these types of hips. Different types of connectors are also used in timber truss construction, such as Trusslock, Cyclone Tie 180, Cyclone Tie 600, nails, GB 340 screws, and Joist Hanger 4090 screws. These connectors help to hold the structure firmly and ensure safety.

CONCLUSION

This study focused on the planning, analysis, and design of a timber residential structure by considering important factors such as wind effects and fire performance. A systematic approach was followed, starting from the development of the building layout, selection of suitable timber materials, and calculation of loads to the analysis and design of structural members.

The results of the study indicate that timber structures can perform effectively under combined loading conditions when proper design procedures are adopted. Wind classification and terrain conditions were found to have a significant influence on structural behaviour, particularly in terms of uplift and lateral stability. This highlights the importance of accurate wind assessment in the design of lightweight timber structures.

Fire performance was also an important consideration in this project. The study shows that timber exhibits predictable behaviour under fire due to the formation of a protective char layer. However, the use of appropriate protective materials and design measures is essential to maintain structural integrity and ensure safety.

The structural analysis carried out for beams, columns, and roof elements confirmed that timber members can satisfy strength, stability, and serviceability requirements when designed systematically. Proper detailing, bracing systems, and connections were found to play a key role in ensuring overall structural performance.

Overall, the study demonstrates that timber is a viable, efficient, and sustainable material for residential construction. With proper planning, analysis, and design considerations, timber structures can provide safe and reliable performance under environmental loads.

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