MASS TIMBER INDUSTRIAL BUILDING OPTIMISATION (MIBO)

Project Big Span
Cost-optimised Industrial Shed Solution

April 2026

CONTENTS

Section 1

EXECUTIVE SUMMARY

Red Stag Timber has developed significant experience in the design and construction of large industrial buildings using engineered timber systems across its Rotorua manufacturing site.

Over the past decade, multiple timber industrial facilities have been constructed using Glulam and Cross Laminated Timber (CLT), providing valuable insights into the structural efficiency, constructability, and economic performance of timber systems for industrial applications.

Project Big Span is a research and development programme undertaken by Red Stag TimberLab to develop cost-competitive timber structural systems for large-span industrial buildings.

The project was initiated following the construction of a 65m × 90m dry storage facility using a full mass-timber portal frame system. The Red Stag Dry Store structure comprised:

- 65 m clear span glulam roof trusses
- Glulam roof struts and wind beams
- CLT portal columns and wind posts

While the building successfully demonstrated the feasibility of large-span timber industrial shed construction, post-construction cost analysis revealed that the structure was 19.3% more expensive than a comparable steel portal frame system (structure only, not overall build cost).

Project Big Span therefore aimed to develop a new structural typology capable of reducing the cost of timber industrial structures by approximately 20%, allowing timber buildings to compete directly with structural steel.

Through structural optimisation and cost analysis, the project identified a hybrid CLT-steel I-beam portal system as the most promising solution.

Engineering assessment and detailed cost modelling demonstrate that this hybrid system has the potential to achieve cost parity with equivalent steel portal frame structures while significantly reducing embodied carbon, creating a pathway for large-span industrial buildings to be constructed using low-carbon timber solutions.

RST Dry Store – As Built

Section 2
BACKGROUND

Red Stag Timber Sawmill

Red Stag Timber has progressively developed a series of large-scale timber industrial buildings at its Rotorua manufacturing site over the past decade. These projects have served as a practical testbed for the application of engineered timber in large-span industrial structures and have informed the development of new structural typologies for the sector.

The Red Stag Timber sawmill has a long history within New Zealand's forestry sector. The Waipa sawmill site was originally established in 1939 by the New Zealand Government and was later acquired by the Verry family in 2003, who continue to operate the site today. Over time, the site has expanded significantly and now covers approximately 1.3km by 0.8km, supporting a range of timber processing and manufacturing operations.

To support these operations, Red Stag Timber has constructed several large industrial buildings using engineered timber structural systems. Key projects include:

- Remanufacturing Building (2011)
- Sawmill Building (2014–2015)
- CLT Manufacturing Facility (2019–2020)
- Pressure Treatment Plant (2022)
- Stacker Building (2022–2023)
- Mobile Plant Workshop (2023)
- Trimline Building (2023)
- CLT Dry Store (2025)

These buildings incorporate a range of engineered timber products including Glulam, Cross Laminated Timber (CLT), and structural sawn timber.

Through the design and construction of these facilities, Red Stag Timber has gained significant experience in the performance, constructability, and economic characteristics of timber structures in industrial applications.

A key objective of these projects has been to explore how timber can be used effectively for large-span industrial buildings, a sector traditionally dominated by structural steel portal frames.

As spans increase, the structural efficiency and cost competitiveness of timber systems becomes increasingly challenging, particularly for buildings requiring clear spans greater than 45 metres.

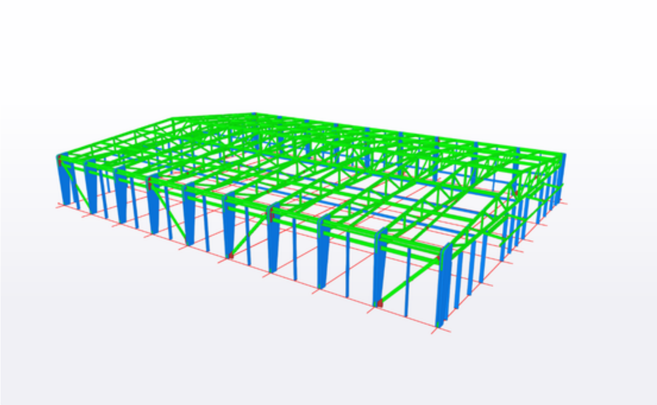
Experience from the Red Stag projects has helped identify structural systems that perform efficiently at different span ranges. For example:

- Up to ~15 m span: Glulam portal frames with glued knee joints
- 15 - 20 m span: CLT portal frames (limited by member length)
- 20 - 30 m span: Glulam portal frames
- 30 - 45 m span: Glulam truss systems

This progression demonstrates that while timber can perform efficiently at smaller spans, larger industrial buildings require increasingly sophisticated structural systems to remain cost competitive with steel.

The construction of the Red Stag Dry Store, a 65 m clear-span timber building, represented a significant milestone in this development process. The building demonstrated the feasibility of large-span timber industrial structures but also highlighted a key challenge: despite its technical success, the structure was more expensive than an equivalent steel portal frame solution.

These lessons provided the foundation for Project Big Span, a research and development initiative aimed at creating a new generation of timber structural systems capable of achieving both large spans and cost competitiveness with steel construction.



RST Dry Store - Green members are Glulam and Blue members are CLT

Red Stag Dry Store

Red Stag TimberLab (RSTL) has been investigating the potential market opportunity for large-span industrial buildings constructed using engineered timber systems. As part of this exploration, Red Stag Timber (RST) constructed a dry storage facility in 2025 measuring 65m wide by 90m long.

The building was designed as a full mass-timber portal frame structure with a 65m clear span, providing a valuable case study for the performance and constructability of timber structural systems at large industrial scale.

The primary structural elements of the building included:

- Glulam roof trusses: The roof structure consisted of glulam trusses measuring approximately 2.5m deep at the knee and 6.0m deep at the apex, with chord members up to 32.6m in length. Glulam was selected for the truss elements due to its efficient bending and compressive strength when the grain is aligned parallel to the span. This allowed the roof structure to achieve high structural efficiency while minimising overall mass.

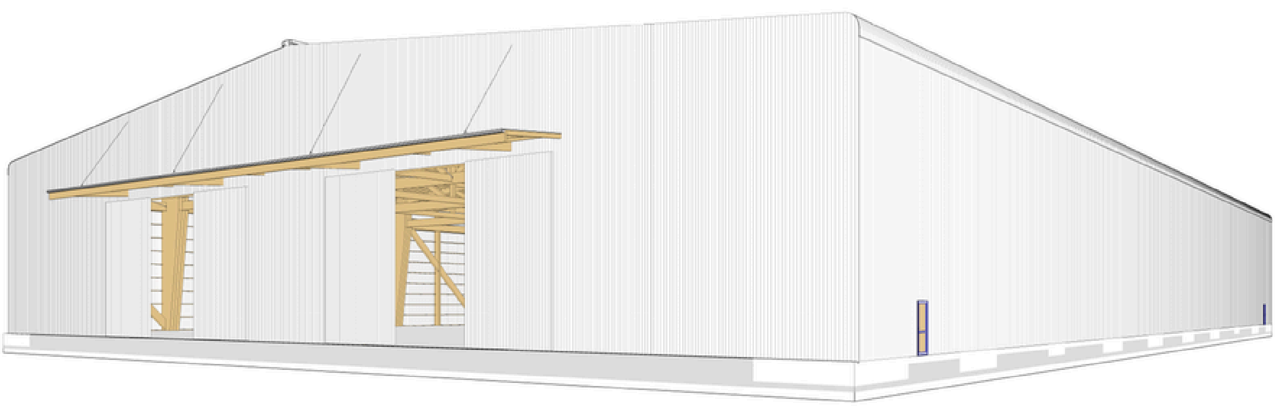
- Glulam wind beams and roof struts: Glulam members were also used for wind beams and roof struts to maintain consistency in the roof structure and to ensure an efficient structural design with minimal weight.

- CLT portal columns and wind posts: Cross laminated timber (CLT) was selected for the portal columns and wind posts. Because column members are primarily subjected to compressive forces and are directly supported by the foundation, member weight is less critical. The multi-layered configuration of CLT panels provides improved buckling resistance and compressive performance, making them well suited to columns carrying high vertical loads. CLT is the cheapest mass timber product available at approximately 50% of the cost of Glulam on a $/m3 basis.

While the Red Stag Dry Store building successfully demonstrated the feasibility of constructing large-span industrial structures using mass timber, a detailed post-construction cost analysis indicated that the timber structural solution was 19.3% more expensive than an equivalent steel structure (structure only, not overall build cost).

This cost differential highlighted the need for further research to improve the economic competitiveness of timber systems for large-span industrial buildings. In response, Project Big Span was initiated as a research and development programme aimed at optimising timber structural systems and reducing the cost gap between mass timber and conventional steel solutions. The project was supported by the Mid-Rise Wood Construction partnership between MPI and Red Stag.

The objective of Project Big Span was to develop a timber structural system capable of reducing the structural frame cost by at least 20% relative to the Red Stag Dry Store as-built timber solution. Rather than refining the existing truss design, the project sought to develop a new structural typology capable of delivering a step-change in structural efficiency.



RST Dry Store – Structural Render

Section 3

RED STAG DRY STORE ASSESSMENT

To evaluate the cost competitiveness of the Red Stag Dry Store, the completed timber structure was compared against pricing obtained for an equivalent steel portal frame building.

Pricing for the steel alternative was provided by a reputable steel shed supplier on 2 May 2025, with a total installed structure-only cost of approximately \$685 per m² (includes portals, purlins & girts, roof bracing and ancillary fixings, shop drawings and installation).

A detailed back-costing analysis of the Red Stag Dry Store demonstrated that the mass timber structural solution was approximately 19.3% more expensive than the equivalent steel structure (structure only, not overall build cost).

This cost differential highlighted the need to further optimise timber structural systems to improve their competitiveness in the large-span industrial building market, and ultimately led to the initiation of Project Big Span.

RST Dry Store - Build in progress

The objective of Project Big Span was to develop a timber structural system capable of reducing the structural frame cost by at least 20% compared with the as-built Red Stag Dry Store mass-timber solution. Rather than making incremental refinements to the existing truss design, the project sought to investigate alternative structural typologies capable of delivering a step-change in structural efficiency and cost performance.

To identify the most cost-effective configuration, a range of column and rafter systems were evaluated. Three column options and four rafter options were developed, resulting in twelve potential structural frame combinations for assessment.

Column Options

Three alternative column systems were considered:

Option A – CLT Column (Baseline Option)

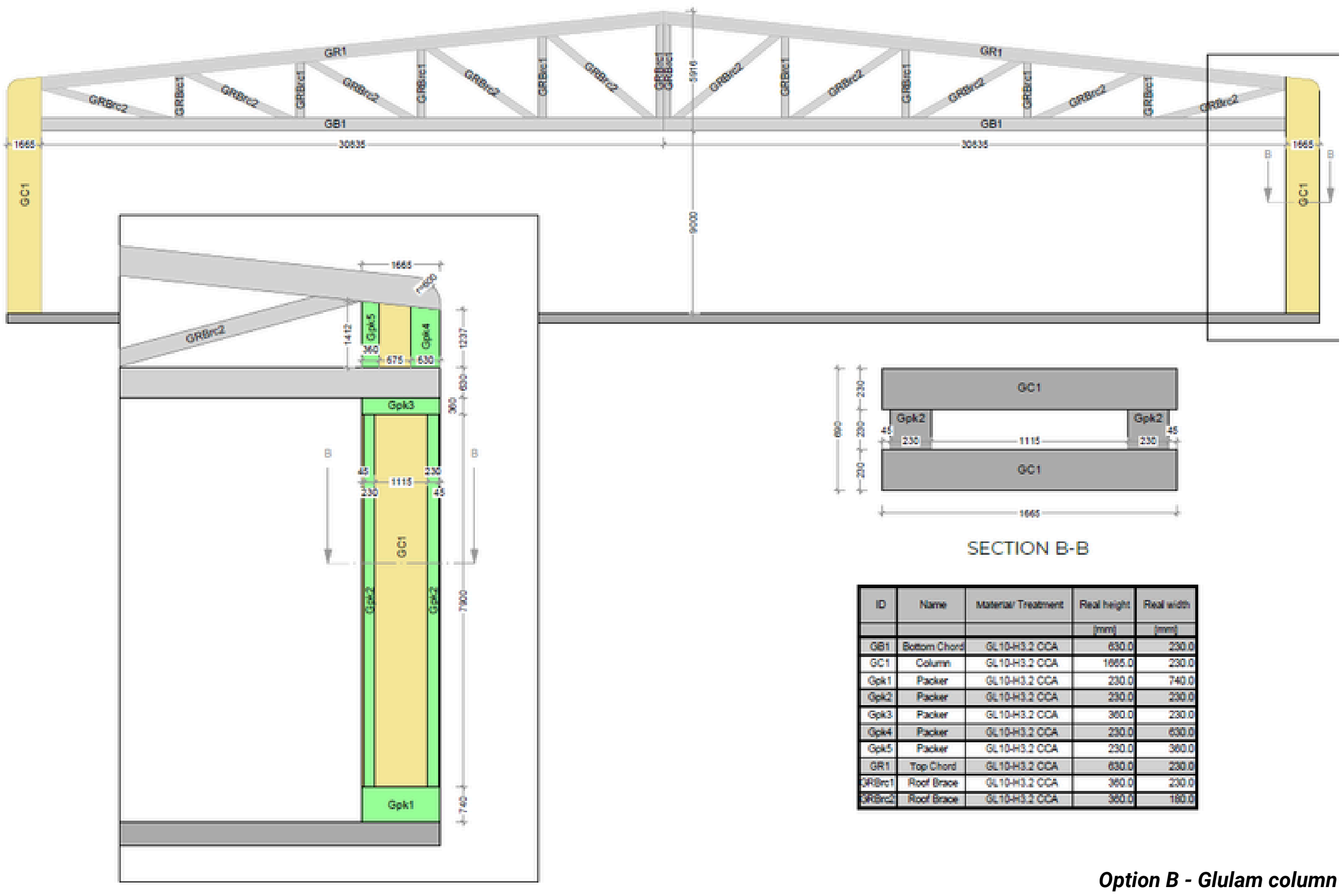
The as-built Cross Laminated Timber (CLT) column configuration used in the Red Stag Dry Store was retained as a baseline for comparison.

Option B – Glulam Column

A Glulam column consisting of two 1665 × 230 mm flanges with 230 mm wide blocking between was investigated. This configuration was intended to provide high bending capacity while potentially reducing material costs compared with CLT panels.

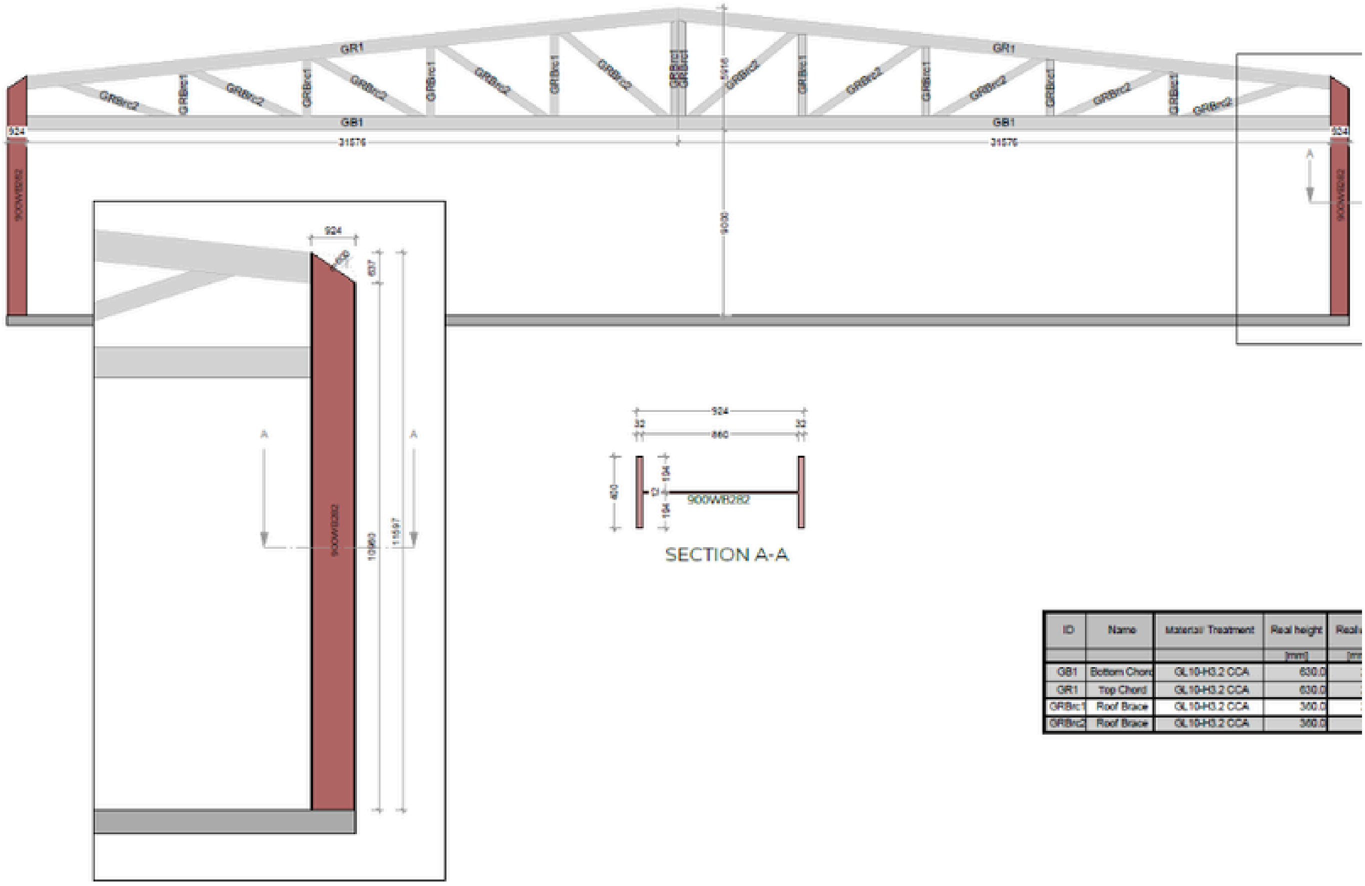
Option C – Welded Steel Column

A structural steel column using a 900WB282 section was assessed as an alternative column solution. Steel columns offer high structural efficiency and reduced member size, which can provide advantages in terms of usable floor area and connection simplicity.



ID	Name	Material/ Treatment	Real height [mm]	Real width [mm]
GB1	Bottom Chord	GL10-H3.2 CCA	630.0	230.0
GC1	Column	GL10-H3.2 CCA	1665.0	230.0
Gpk1	Packer	GL10-H3.2 CCA	230.0	740.0
Gpk2	Packer	GL10-H3.2 CCA	230.0	230.0
Gpk3	Packer	GL10-H3.2 CCA	360.0	230.0
Gpk4	Packer	GL10-H3.2 CCA	230.0	630.0
Gpk5	Packer	GL10-H3.2 CCA	230.0	360.0
GR1	Top Chord	GL10-H3.2 CCA	630.0	230.0
GRBrc1	Roof Brace	GL10-H3.2 CCA	360.0	230.0
GRBrc2	Roof Brace	GL10-H3.2 CCA	360.0	180.0

Option B - Glulam column



Option C - Steel Column

Rafter Options

Four alternative rafter systems were considered:

Option 01 – Hybrid Steel and Glulam Truss 01

This option consisted of a hybrid truss with steel SHS diagonal members and Glulam vertical members and chords. To improve material efficiency, all Radiata Pine was replaced with Douglas Fir, making use of a lower-cost fibre resource. The design also assumed approximately 10% savings in connection costs through truss redesign and simplification of fixings.

Option 02 – Hybrid Steel and Glulam Truss 02

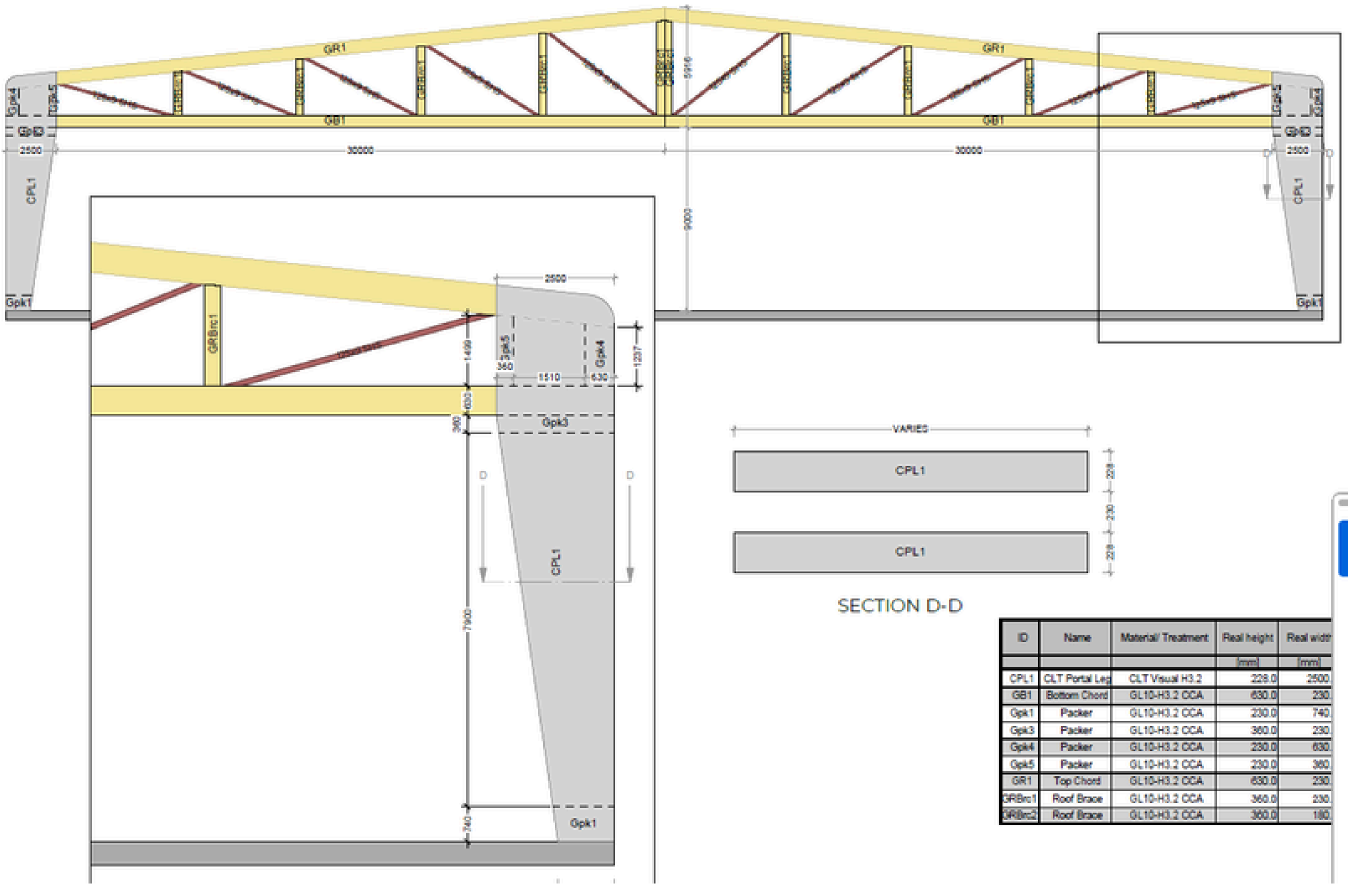
This concept used RHS steel chords and SHS diagonal members at the knee region, with Glulam members used elsewhere in the truss. Similar to Option 01, Radiata Pine was replaced with Douglas Fir to utilise a cheaper fibre resource, and a 10% reduction in connection costs was assumed through redesign of the truss connections, truss optimisation and improved connection detailing.

Option 03 – Hybrid I-Beam Rafter

This option investigated a composite I-beam rafter consisting of a CLT web with steel PFC flanges. The concept relied on composite behaviour between the web and flanges to achieve an efficient long-span structural member. The nominal rafter depth for this configuration was assumed to be approximately 3 metres.

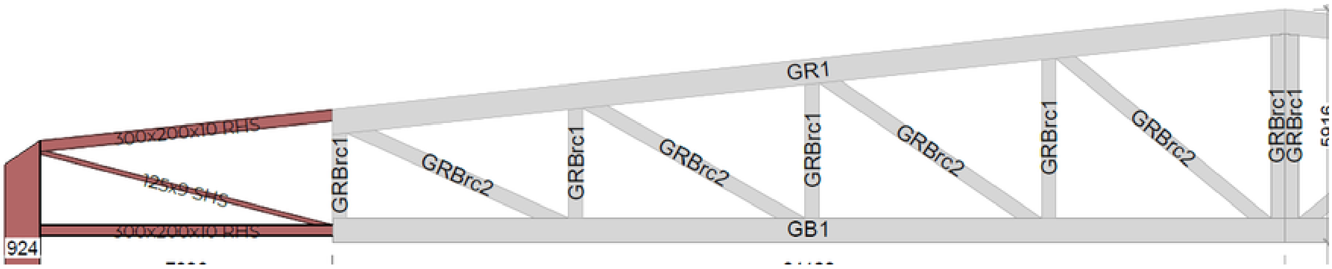
Option 04 – Douglas Fir Timber Truss

This option retained the overall truss geometry of the as-built Red Stag Dry Store design but replaced all Radiata Pine with Douglas Fir to take advantage of a cheaper fibre resource. As with the other truss options, a 10% reduction in fixing costs was assumed through truss optimisation and improved connection detailing.

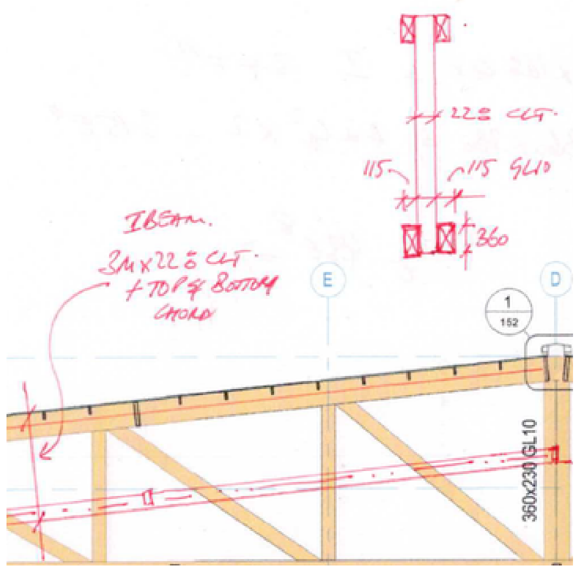


ID	Name	Material/ Treatment	Real height	Real width
			[mm]	[mm]
CPL1	CLT Portal Leg	CLT Visual H3.2	228.0	2500.
GB1	Bottom Chord	GL10-H3.2 CCA	630.0	230.
Gpk1	Packer	GL10-H3.2 CCA	230.0	740.
Gpk3	Packer	GL10-H3.2 CCA	360.0	230.
Gpk4	Packer	GL10-H3.2 CCA	230.0	630.
Gpk5	Packer	GL10-H3.2 CCA	230.0	360.
GR1	Top Chord	GL10-H3.2 CCA	630.0	230.
GRBrc1	Roof Brace	GL10-H3.2 CCA	360.0	230.
GRBrc2	Roof Brace	GL10-H3.2 CCA	360.0	180.

Option 01 - Hybrid Steel and Glulam truss



Option 02 - Hybrid Steel Knee truss



Option 03 - I-Beam Rafter

Cost Analysis

Detailed pricing analysis compared each structural system. The analysis showed that the hybrid I-beam rafter combined with steel columns produced the lowest structural cost. All hybrid I-beam configurations achieved costs below the steel benchmark.

Structural System	Relative Cost
Existing timber truss	119%
Hybrid truss options	102% - 108%
Hybrid CLT I-beam	96% - 99%

The preliminary assessment indicated that the hybrid I-beam concept had the potential to achieve cost parity with conventional steel construction. On this basis, it was recommended that the project proceed to a more detailed design and cost analysis focused on the hybrid I-beam rafter system.

Where possible, the preferred outcome would be to achieve an efficient structural solution using a hybrid I-beam rafter and column to maximise the use of mass timber within the primary structure.

Section 5
HYBRID CLT-STEEL I-BEAM SYSTEM

Design Criteria

Red Stag TimberLab (RSTL) engaged CREATE to undertake an initial engineering assessment of the proposed hybrid I-beam rafter portal frame system. A preliminary structural analysis was undertaken using the following design criteria:

- Design Life: 50 years, Importance Level 2.
- Soil Classification: Class D soils.
- Seismic Hazard: Seismic hazard factor Z = 0.18, representing the Hamilton and upper North Island region. (Note: additional design considerations would be required for sites located in higher seismic regions.)
- Site Conditions: Flat site with no significant topographical features influencing wind or seismic loading.
- Terrain Category: Terrain Category 2, representing open rural areas with few obstructions, but not located in coastal or estuarine environments.
- Building Openings: Shed openings configured to limit the internal pressure coefficient (Cpi) to a maximum of +0.2 / −0.3.

The preliminary structural concept developed for assessment incorporated the following building geometry:

- Overall dimensions: 90m long × 65m wide
- Portal spacing: 9m (10 bays)
- Underside knee height: 9m
- Roof pitch: 5 degrees

A 9m portal spacing was selected to accommodate typical industrial building functionality, allowing for an 8m wide roller door with an additional 1m allowance for a pedestrian access door.

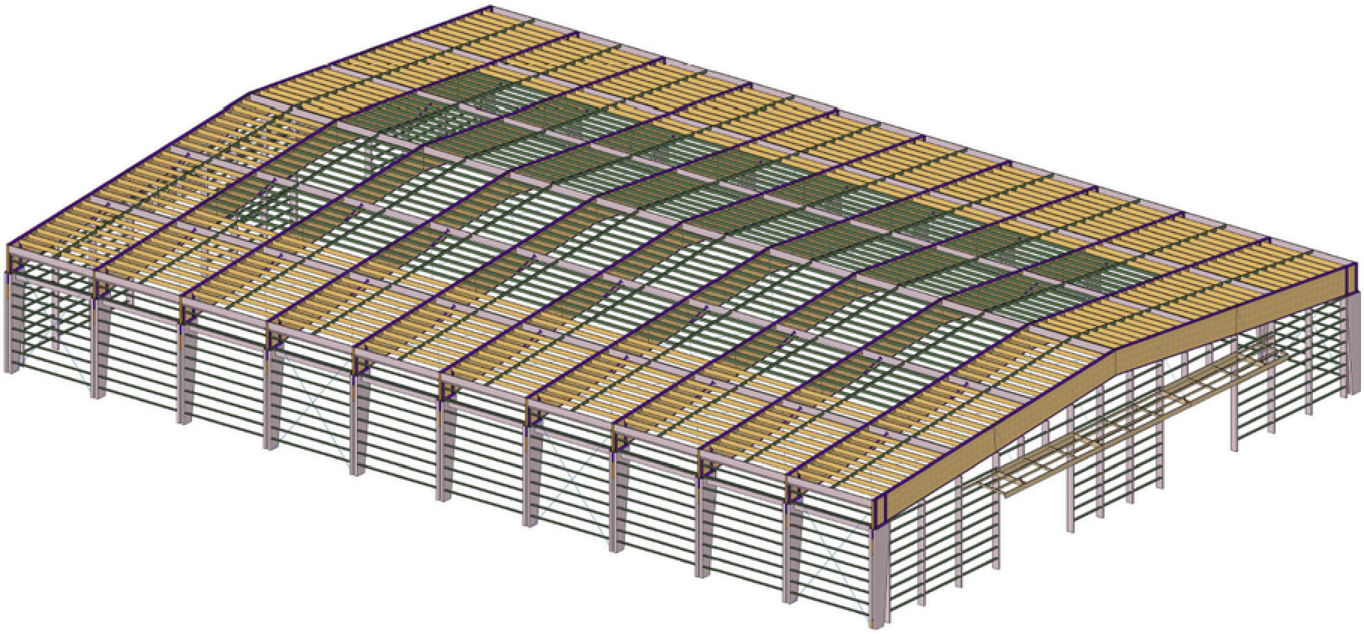
Consideration was required to ensure movement compatibility between the steel flanges and timber web could be overcome with mechanical fixings. Finite Element Models were developed, and shear testing was undertaken to validate the strength and stiffness of the screw fixings.

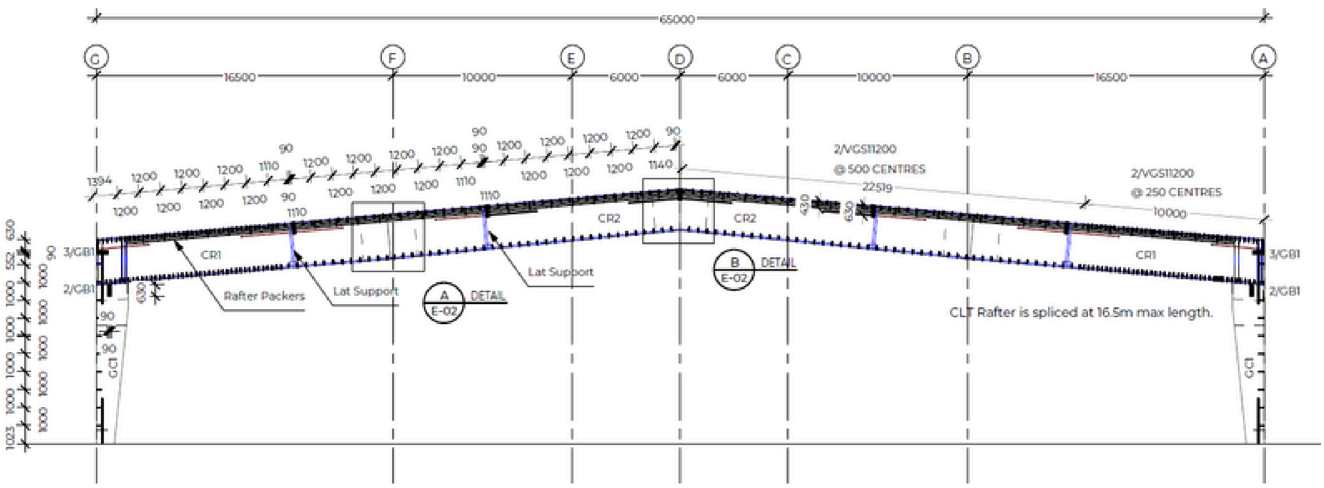
Pricing

The optimised hybrid I-beam structural solution was benchmarked against the back-costing analysis of the as-built Red Stag Dry Store. The assessment indicated that the hybrid structure system was 21.9% less expensive than the as-built solution, resulting in a structure that is approximately 2.6% cheaper than an equivalent structural steel portal frame (structure only, not overall build cost).

The following assumptions were adopted in the cost comparison:

- A structural contingency allowance of $300,000 was applied to the hybrid I-beam timber option, reflecting that the detailed design was not yet fully developed. Some refinement remains around connection detailing for secondary members and the final specification of the lateral bracing system.
- Installation labour for the hybrid I-beam timber option was assumed to be equivalent to the steel installation labour rate. The proposed portal frame incorporates bolted connection details that are comparable to conventional steel portal frame construction, resulting in similar erection methodologies and installation timeframes.





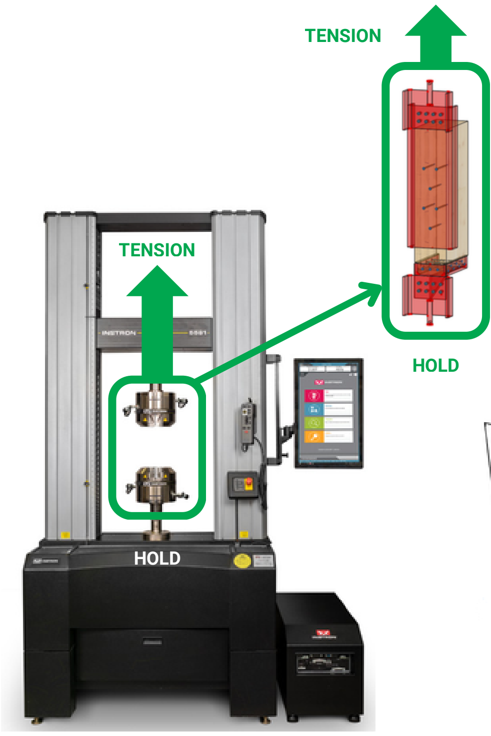
RST Dry Store – structural concept using optimised hybrid I-beam system

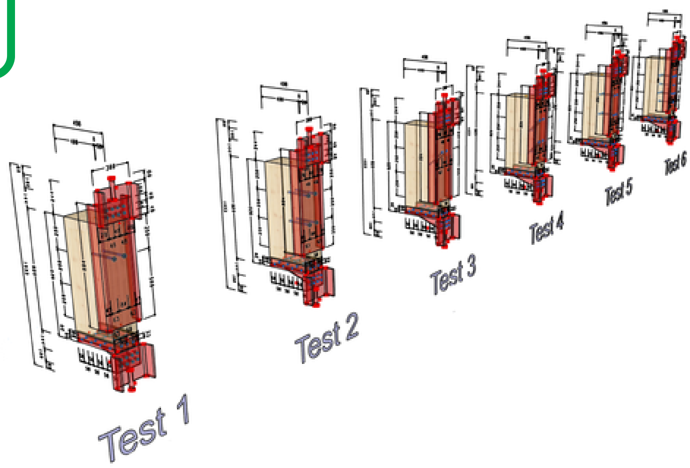
Section

CASE STUDY – COMMERCIAL INDUSTRIAL BUILDING APPLICATION

To support the development of the hybrid I-beam system, Red Stag TimberLab partnered with the University of Waikato to conduct a series of laboratory tests to validate the structural behaviour of the proposed composite section and connection detailing. The testing focused primarily on the interaction between the CLT web and the steel flange elements, with particular attention given to the performance of the mechanical fasteners used to achieve composite action.

Test specimens were assembled using the proposed connection configuration and loaded to evaluate shear transfer capacity, stiffness characteristics, and potential failure modes. The results confirmed that the selected fastening system provided effective load transfer between the web and flange components, enabling the section to behave as a composite structural member. The testing also provided valuable data for refining screw spacing, connection detailing, and overall structural modelling assumptions used in the engineering design.





To complete the Laboratory Testing validation, additional full-scale testing is required. RSTL is currently planning a series of full-scale 4-point bending tests and later in 2026 will conduct full-scale knee joint tests.

The 4-point bending test is a simpler test compared with the full-scale knee joint testing and will allow RSTL to bring the composite I-Beam solution to market faster as a “rafter only” solution. The advantage of a “rafter only” timber option is:

- A steel leg will be smaller than the hybrid I-beam timber option and will optimize the usable floor space.
- The fixing details at the base, knee and canopy connections will be similar to a traditional steel design.
- The “rafter only” solution is not as novel as the full portal frame option which will simplify the design and consenting process.
- Because the “rafter only” solution is directly substitutable with a steel alternative, this can be specified in the tender documentation as one of several options which will maintain the opportunity for a competitive tender.

Section 7
CASE STUDY – COMMERCIAL INDUSTRIAL BUILDING APPLICATION

To further validate the commercial viability of the hybrid timber structural system developed through Project Big Span, the concept was applied to a proposed large-scale industrial warehouse development in Auckland. The project involved the design of a 171m × 88m industrial building, incorporating a central steel support line to create two 44m clear spans.

The proposal utilised the hybrid I-beam timber solution for both the rafter and column, forming 15x primary portal frames along the building. The portals were designed to provide structural stiffness equivalent to a conventional steel portal frame system while utilising a composite section consisting of a CLT web with steel PFC flanges.

The proposed structural configuration incorporated a 210mm thick five-layer CLT web with 300PFC steel flanges, designed to act as a fully composite member through mechanical coach screw fasteners. Portal frames were connected through bolted steel knee and apex connections, allowing the system to utilise conventional steel-to-steel connection detailing for predictable load transfer and efficient on-site assembly. Secondary structural elements, including purlins, girts, roof struts and bracing, were assumed to be consistent with the equivalent steel structural solution.

The presence of a steel top flange in the hybrid I-beam also allows cleat connections for secondary members to remain similar to those used in a conventional steel portal frame solution.

A preliminary budget estimate prepared for the project indicated that the hybrid I-beam system could be delivered for approximately $3.14 million for the primary portal frames. Feedback received from the developer indicated that this pricing was competitive when compared with a conventional structural steel portal frame solution.

In addition to the economic assessment, an independent carbon analysis was undertaken to compare the hybrid portal system with the equivalent steel portal frame design. The analysis indicated that the hybrid timber structure would result in a total net embodied carbon of 307,837 kg CO_2e, compared with 959,036 kg CO_2e for the steel alternative, representing a r**eduction of approximately 651 tonnes of CO_2e across the project**.

This case study demonstrates that the hybrid structural system developed through Project Big Span can be applied to real commercial projects while delivering cost competitiveness and substantial reductions in embodied carbon compared with conventional steel portal frame construction.

Section 8

CONCLUSIONS

Project Big Span demonstrates that hybrid timber - steel structural systems have the potential to deliver large-span industrial buildings that are both cost-competitive with steel and significantly lower in embodied carbon.

The research programme was initiated following the construction of the RST Red Stag Dry Store, which successfully demonstrated the technical feasibility of a large-span mass timber industrial building but highlighted a cost gap relative to conventional steel portal frame construction. In response, Project Big Span investigated alternative structural typologies capable of improving structural efficiency and reducing material costs.

Through a systematic evaluation of multiple column and rafter configurations, the project identified a hybrid CLT–steel I-beam structural system as the most promising solution. Detailed cost analysis indicated that this system has the potential to achieve a cost advantage, relative to conventional steel portal frame structures.

Laboratory testing was undertaken to validate key structural assumptions within the hybrid beam system, including the performance of the mechanical fasteners used to transfer shear forces between the CLT web and steel flange members. The results of this testing provided confidence that the proposed connection system can achieve reliable composite behaviour between the timber and steel components, supporting the structural design assumptions used in the project.

To further assess commercial feasibility, the hybrid system was applied to a real-world industrial warehouse proposal. The case study demonstrated that the hybrid portal frame system could compete directly with a conventional steel solution while achieving a substantial reduction in embodied carbon, reinforcing the viability for commercial applications.

As part of the commercialisation strategy, Red Stag TimberLab intends to initially promote a “rafter-only” hybrid solution, where the hybrid CLT-steel beams replace conventional steel rafters while retaining the steel columns. This approach offers several advantages:

- It allows the hybrid rafters to be directly substituted for steel rafters in conventional portal frame designs.
- The connection details at the base, knee, and canopy locations remain consistent with existing steel design practices, simplifying engineering approval and construction.
- Steel portal columns minimise the structural footprint of the building frame, maximising usable internal floor space.
- The reduced level of structural novelty simplifies design, consenting, and market acceptance during early adoption.

By introducing the system through a rafter-only configuration, the technology can be incrementally integrated into the existing industrial building market, reducing risk while demonstrating the performance and cost advantages of hybrid timber structures. The intention is to supply full portal configurations once market acceptance has been demonstrated.

Overall, Project Big Span provides strong evidence that hybrid timber–steel structural systems represent a practical pathway for decarbonising large-span industrial buildings at no additional cost. With further development, testing, and standardisation, the system has the potential to enable cost-competitive timber structures across a wide range of industrial building applications.

Contributors:
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ABOUT THE MID-RISE WOOD CONSTRUCTION PROGRAMME

Mid-Rise Wood Construction is a partnership between the Ministry for Primary Industries (MPI) and Red Stag Investments Ltd. The aim of this programme is to encourage widespread adoption of precision-engineered timber in mid-rise building construction. Since its inception in 2018, the programme has assembled a pool of New Zealand professionals experienced in mid-rise wood building design and construction to help share and grow knowledge and expertise with the broader industry.

Engineered timber is not only naturally beautiful but also provides a very strong, low carbon and comparably low-cost alternative to steel & concrete. It is easy to transport, relatively light, and has outstanding earthquake and fire resilience.

The use of prefabrication can decrease construction time by as much as 30 percent, and reduces costs compared with traditional building methods. Combining Cross-Laminated Timber (CLT), laminated veneer lumber (LVL), glulam and panelised framing timber creates a cost-effective, fast, resilient and sustainable system for mid-rise construction.