LIGHTWEIGHT STRUCTURES FOR A PRICE
CASE STUDY OF THE WANNEROO INTERNATIONAL NETBALL STADIUM

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Abstract

Lightweight tension structures are often passed over by engineers and architects because they are perceived to be a relatively high cost solution. This paper sets out a case study showing how the team for the Wanneroo International Netball Stadium worked up a solution to produce a stunning lightweight tension structure that sets this building apart from other similar centres, for a very modest sum.

1. INTRODUCTION

The Wanneroo International Netball Stadium forms part of the Kingsway Sports Complex in Landsdale, Perth, Western Australia. The complex houses four timber floored courts, function facilities, change rooms, sports clinic, fitness centre, creche and a coffee shop.

The brief for the project was to provide a facility that would be the centre for netball in Western Australia for a budget of $3.7M. Given the budget constraints and the client's expectation of the facilities to be provided, it would have been very easy to opt for a conventional structural solution.

2. ARCHITECTURAL CONCEPT

The Architects, Cox Howlett & Bailey decided to pursue a solution where a delicate structure would be the feature that defined this centre, as there was little money for high quality finishes. Therefore, the brief to the structural design team at Connell Wagner was to provide a lightweight truss solution for the main hall and an external frame with an elegant appearance. Detailing was very important as the joints were all fully exposed.

The large floor area lent itself to a long span steel structure. Conventional portal frames were considered but these, whilst economical, did not enhance the internal or external aesthetics, because of the already 'boxy' building shape. The Architects challenged Connell Wagner to develop a lightweight, economical structure and use the resultant cost savings in the design solution to pay for the special detailing and the more sophisticated fabrication and erection.

In essence, the brief was quite simple: develop a structure system which is elegant and visually appealing, but economical to build.

3. STRUCTURAL SOLUTION

The Architect's Brief appeared straightforward, but it was extremely challenging and required intense and sometimes passionate interaction with the Architect to meld the Architect's intent and the Engineer's needs in order to bring about the elegance with the required economy.

To bring about the desired outcomes required us to put forward a solution, then refine the design and detail with the assistance of the Architect, to ensure all elements of steelwork were optimised both in a structural sense and for visual appeal. The Engineer in this role required a passion and a real feel and sense of proportion and space to practice the true art of Engineering.

The final solution consisted of ten delicate bowstring trusses spanning 39 m over the main hall providing a circular arched roof over the sports hall. The top chord continued as a rafter spanning a further 14 m over the adjoining amenities wing. Bay spacing is typically 7.8 m. The trusses were supported on steel tube columns that tied down externally with VSL high strength rods to provide resistance uplift through catenary action. This required careful repetitive detailing, rationalisation and use of proprietary products where possible. The perimeter walls of the structure are constructed of concrete tilt-up panels, 170 mm thick and 6.5 m tall.

The highly visible structural steel frame forms a dominant architectural feature of the sports hall. The bowstring trusses behave non-linearly under non-uniform load, providing a complex structure for analysis. Due to the large span of the trusses, V-shaped web members were used to improve the in-plane stiffness, thus helping to resist the non-uniform loads. The structural analysis package, SpaceGas, was used to analyse both the individual frames and the braced end bay frames. Dead and live loads were resisted by truss action, but the net wind uplift was carried by axial tension and bending in the top chord, which was anchored at each end by the external columns and tie down rods.

A 273 mm diameter Circular Hollow Section was used for the top of the bowstring truss while the bottom chord comprises of VSL MT600 series bar and proprietary fittings. The bar diameter is typically 36 mm.

The uplift reactions at each of the curved top chords were substantial, and were resisted by pairs of VSL MT600 tie rods fixed to the pile caps that, in turn, are held in place by two to four tensioned ground anchors. Several anchors were proof loaded to confirm their capacity. The tie down rods were up to 42 mm diameter. A single Circular Hollow Section compression strut with purpose designed pins and plates, completed the truss tie down system. The struts were originally detailed with tapered ends, but these were deleted because of cost. Refer to the following sketches for a typical frame section and details.

Cross braced rods were used for end wall roof bracing to maintain the light feel of the structure.

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The utilisation of high strength steel enabled a very light roof structure to be achieved, approximately 11.8 kg/m^2 (weight of truss, purlins, bracing and tie downs for a typical bay spanning to the amenities wing). The use of standard VSL couplings and joiners helped to keep the costs down. Despite the higher cost of the VSL system per tonne over mild steel, the savings in weight and ease of construction resulted in a solution which provided only a small premium, whilst also maintaining the aim of achieving a lightweight, elegant and pleasing structural form.

4. ATTENTION TO DETAIL

Close attention to detail in the design of the connections and careful sizing of members was critical to ensure that the desired architectural aesthetics could be achieved. The connections were designed in close co-operation with the Project Architects, Cox Howlett & Bailey, and Connell Wagner to ensure that the result would satisfy the requirements of both parties. This required a high quality of documentation to ensure a successful structure. The attached photographs and details show some of the complex connections that were used in the building.

5. EASE OF FABRICATION AND ERECTION

Because of the lightweight, simply supported nature of the structure, the builder was able to incorporate an innovative erection system which saved time, cost and provided a safer erection sequence. The three metre deep trusses were assembled on site at ground level and lifted into place in pairs, complete with purlins. Typically, one site welded splice was made in each top chord, except for the trusses where the top chord spans to the amenities area, where two welded splices were required.

A special jig constructed by the fabricator assisted in assembling the trusses to the required profile. The ability to assemble major components of the roof structure on the ground aided in meeting Occupational Health and Safety requirements.

6. PERFORMANCE AND DURABILITY

Galvanising of exposed steelwork followed by high performance paint treatments internally and externally, together with Colorbond cladding and tilt-up concrete perimeter walls will ensure a functional and durable structure.

7. THE CLIENT'S RESPONSE

The client's project coordinator and centre manager was very pleased with the final product. "*The building has been a huge success and looks $2M more than its budget. The steel theme is brilliant. The Architectural team and Builder have matched our dreams with reality*."

The project was short-listed in the 1997 AISC Engineering Steel Design Award in Western Australia.

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8. SUMMARY

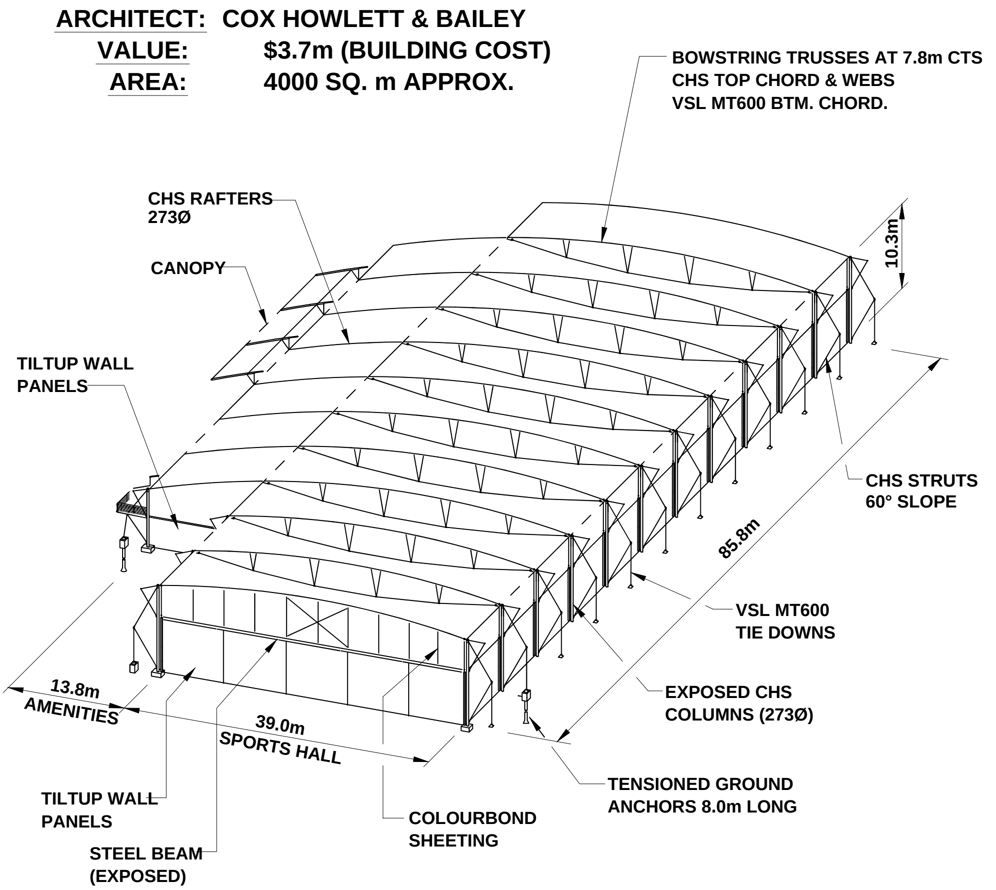
In summary, Connell Wagner, working closely with the Architects, have combined their skills to create a visually stunning, yet functional structure that defines this facility, by adopting an economical lightweight solution.

The lesson that was learned from this project was not to pass over lightweight structures for tight budget projects. The premium can be negligible by getting synergy between the Architect and the Structural Engineer, allowing optimisation of the structure and making detailing work an architectural feature.

PROJECT DETAILS

Construction Commenced: February 1997
Construction Completed: September 1997

Client: Wanneroo District Netball Association
Architect: Cox Howlett & Bailey Architects & Planners
Structural Engineer: Connell Wagner
Builder: BGC Pty Ltd
Steel Fabricator: Metro Lintels


ARCHITECT: COX HOWLETT & BAILEY
VALUE: $3.7m (BUILDING COST)
AREA: 4000 SQ. m APPROX.
BOWSTRING TRUSSES AT 7.8m CTS
CHS TOP CHORD & WEBS
VSL MT600 BTM. CHORD.
CHS RAFTERS
273Ø
CANOPY
TILTUP WALL
PANELS
10.3m
CHS STRUTS
60° SLOPE
85.8m
VSL MT600
TIE DOWNS
EXPOSED CHS
COLUMNS (273Ø)
13.8m
AMENITIES
39.0m
SPORTS HALL
TENSIONED GROUND
ANCHORS 8.0m LONG
TILTUP WALL
PANELS
COLOURBOND
SHEETING
STEEL BEAM
(EXPOSED)

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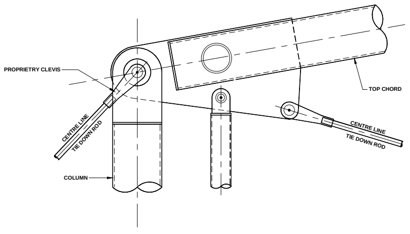
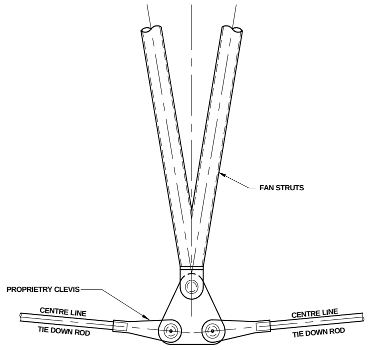


TYPICAL COLUMN CONNECTION



TYPICAL BOTTOM CHORD TIE CONNECTION

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