This case study was written at the time when OneSteel was part of BHP. In that context, in some instances within this case study, reference may be made to BHP.

300PLUS® keeps P&O in the freeze

The requirement to expose structural steel to -25^{0}C temperatures in the construction of P&O Cold Storage's recently completed $9000m^2$ cold storage facility at Laverton, Victoria, provided both engineering challenges and rewards for structural and civil consultant, Davis Naismith. The facility provides low temperature warehousing for perishable foodstuffs for domestic distribution as well as the export container market.

The $10 million design and construct tender was won by the prestigious builder Vaughan Constructions. Victorian-based in the industrial building market since 1955, they expanded to Sydney two years ago. Architect Scott Sheldon Design worked with Davis Naismith on the design team.

Building Requirements

The purpose of this facility is for the storage and distribution of chilled and frozen food products for retail and general warehousing customers. Required design temperatures were -25^{0}C for the freezer store and -4^{0}C for the annex loading area. P&O required the facility to be designed and constructed in a manner reflecting the standard of operational function, visual appearance and overall quality that had already been set by P&O on other projects throughout Australia and overseas.

The major requirements were as follows:

- Building construction to achieve an effective life span of 30 years.
- Lowest possible energy usage and running costs.
- Preservation of refrigerated air by efficient use of an insulated envelope at -25^{0}C.
- Provision of a fully panel-clad building in order to satisfy the above requirements and to achieve the client's aesthetic preference.

P&O specified internal framing due to thermal efficiencies. Penetrations had to be kept to a minimum because of the cost of achieving insulation and preventing condensation.

The requirement to expose structural steel to the -25^{0}C environment inside the main warehouse structures presented a major structural and commercial challenge.

Tony Davis from Davis Naismith said: "We had to come up with a competitive solution on a design and construct project for a problem where the implications of detailing for cold temperatures and the effect on brittle behaviour of steel were not generally well understood. Routine textbook solutions were not available.

We investigated several steel supply options to satisfy the cold temperature requirements, including using built-up sections from plate and also at importing special low temperature structural sections. We finally determined that the only way we could meet the tight program constraints was to use 300PlUS® structural sections. The technical support and quality of BHP Steel were also important considerations".

AS 4100 Section 10 BRITTLE FRACTURE requires steel grades to be used in circumstances such as those demanded by the P&O facility, be selected either by the notch-ductile range method or by using a fracture assessment employing fracture mechanics analysis, fracture toughness requirements and non-destructive testing of the steel grade selected.

The notch-ductile range method could not be used due the unavailability of rolled sections in L15 grade steel and the limitation of member thicknesses to 10mm, which would require all structural members to be designed and fabricated as built-up sections using a maximum plate thickness of 10mm.

A fracture mechanics assessment method was developed in consultation with BHP Integrated Steel's Technical Services Section which enabled the use of the following grades of steel in rolled sections at -25^{0}C:

300PLUS®	All sections except angles
Grade 250	Angle sections
Grade 350	Plate
Grade 350	Square Hollow Sections

Structural Framing System

Lateral stability was provided by roof wind trusses and wall bracing. The use of a fully braced structure resulted generally in lower stresses and thinner section thicknesses compared with a portal solution, which helped satisfy cold temperature design requirements for steel. The primary trusses, secondary beams and battened purlins were designed typically with notional pin joints.

Structural Design

A structural framing system involving primary trusses, secondary beams and battened purlins supporting sandwich panel roof and walls spanning up to 6.5m was developed to meet the dual needs for low stress levels and economy of structure. The low stress levels were required due to the problems associated with stress concentrations and potential for brittle fracture under low temperature. As the project was a competitive design and construct tender, the solution obviously needed to be economical. The use of 200mm and 250mm sandwich panels with steel COLORBOND® cladding also achieved the requirements for lower energy usage and preservation of refrigerated air in the -25^{0}C envelope.

The design solution achieved the above requirements with the combination of large span sandwich panel roofing and walling, enabling larger effective lengths for major structural members, which in turn resulted in lower stress levels without loss of overall economy of structure and building.

Special structural considerations for the cold temperature application included:

1. A 12m external stairway which needed to be freestanding to eliminate ties which would have caused insulation problems at building penetrations.
2. The use of secondary batten purlins with long effective lengths to provide reduced stresses, which, combined with the thin section thickness, offered an efficient means of ensuring ductility.
3. Trusses were fully bolted using T-gussets for connecting web members to the top and bottom chords. The elimination of welded gussets reduced the potential for brittle fracture.
4. Reduced stress levels. Davis Naismith used the Canadian Steel Code for guidance on allowable stress levels. The procedure looked at the importance of the member and was used for choosing the most critical sections for testing. Typically, maximum working stress levels were 20% of yield for critical areas and 30% of yield for less critical areas.
5. All bolt holes were drilled, not punched. Holes were not permitted to be reamed or enlarged to avoid crack initiation.
6. All plates and sections were flame or saw cut, not guillotined. Flame cut edges were ground flush to avoid crack initiation
7. Since the quality of welding is critical in achieving low susceptibility to brittle fracture initiation, no undercut or excessive weld reinforcement was permitted. Smooth and uniform weld surfaces were required. Strict inspection procedures were specified since welds will encounter fatigue problems if defects are present either between the parent metals (undercut, blowholes, etc.) or inside the weld (slag impurity).

Connections

Critical connection cases were identified and assessed by BHP Integrated Steel's Technical Services Section using CRACKWISE Version 1.135. The detailing of connections was then developed around this fracture mechanics assessment method using the case studies shown (right):

Testing

Steelwork fabricated for the -25⁰C environment, was subject to rigorous testing and material selection procedures which included the following:
(i) Identification of heat numbers from mill supply batches.
(ii) Charpy V Notch testing of mill samples from the batches.
(iii) Identification of heat numbers on all material.
(iv) Weld procedures and consumables.
(v) Weld inspection, testing procedures.
(vi) Drilling and cutting procedures.

Summary

The combined efforts of the project team, in particular the innovative structural consultant with the assistance of BHP's technical back-up, helped ensure that a solution to the use of rolled steel sections in -25⁰C environments was developed and implemented successfully within tight time and budget constraints imposed by the design and construct tender conditions of this project.

The efforts of Davis Naismith were recognised when they won the 1997 AISC Steel Award (engineers category) in Victoria, for the project.

Client:	P&O
Builder:	Vaughan Constructions
Structural and Civil Engineers:	Davis Nasmith
Architect:	Scott Sheldon Design
Fabricator:	Page Steel Fabrications
Detailer:	Precision Design
Distributor:	Union Steel
Weld Procedures:	VWS Staff
Weld Testing:	ETRS

P&O cold storage facility under construction

Case 1

A chord of a truss, loaded in tension to an ultimate load of 360kN (1.5 x working load) to give an ultimate stress of 70 MPa. Location at bolted joint between chord and vertical and diagonal truss members.

Section: 300 PFC hot-rolled steel parallel-flange-channel, 300x90mm, Grade 300PLUS®. Flanges 16mm, web 8mm thick.

Working temperature: -25⁰C

Material properties: Web yield stress 320 MPa, tensile strength 440 MPa (at normal atmospheric temperature, assumed 20⁰C, from BHP Hot Rolled Products brochure). Maximum 40J transition temperature = -35⁰C.

Case 2

A bolted and welded end-connection on an I-beam rafter, loaded in bending to an ultimate stress of 177 MPa (1.5 x working load) in the flange.

Section: 360 UB 45 hot-rolled steel Universal Beam (I-beam), 352x171mm, Grade 300 PLUS®. Flanges 9.7mm, web 6.9mm thick.

Working temperature: -25⁰C

Material properties: Web yield stress 320 MPa, tensile strength 440 MPa (at normal atmospheric temperature, assumed 20⁰C). Maximum 40J transition temperature = -35⁰C.

Case 3

A 25mm thick steel endplate, welded to the end of a 360 UB 45, to bolt the beam to a supporting column.

Section: Endplate: 200x450x25mm thick, Grade 350 to AS 3679.1

Beam: 360 UB 45, Grade 300PLUS®

Welds: full penetration butt welds on flanges, continuous 6mm fillet welds on web.

Working temperature: -25⁰C

Materials properties:

Plate: yield stress 340 MPa, Ultimate Tensile Strength 440 MPa (assumed ambient temperature 20⁰C)

Beam Web: yield stress 320 MPa, Ultimate Tensile Strength 440 MPa (assumed ambient temperature 20⁰C)

Weld: properties taken as the minimum strength base metal (beam web).

Case 4

A square hollow section tie beam, bolted at the ends to the tops of columns, with longitudinal welded-on angle brackets (clips) to attach wall and ceiling panels.

Section: 250x250x6mm SHS (square hollow section), Grade C350 to AS 1163.

Working temperature: -25⁰C

Materials properties: Square hollow section yield stress 350 MPa, Ultimate Tensile Strength 450 MPa (assumed ambient temperature 20⁰C).

The above assessments confirmed that stress concentrations were within acceptable limits at critical locations and proved the design.