Structural Stainless Steel Case Study 04

Armada Platform Accommodation Modules

The Armada Platform is operated by BG Group and exploits three gas and condensate fields in the Central North Sea, 250 km east of Aberdeen. It comprises a four legged steel spaceframe jacket supporting a single integrated deck containing wellhead, process and accommodation facilities. The living facilities on the platform required extending to accommodate 59 personnel. Four blast and fire rated accommodation modules and two walkway modules linking the new modules to the existing accommodation were added to the platform in 2009. The structural cladding of these modules was corrugated stainless steel.

Material Selection

While carbon steels need regular repainting and maintenance in harsh offshore environments, stainless steels typically require little maintenance. The installed modules have only small gaps between units and cantilever over the edge of the platform making maintenance both difficult and risky. Therefore, the client stipulated that all steel exposed to external conditions should be stainless, in order to avoid a costly maintenance budget over the 30 year design life.

The structural cladding was made from austenitic stainless steel grade 1.4401 (S31600) with a 2B standard mill finish in accordance with EN 10088-2 [1]. This grade also exhibits adequate retention of strength and stiffness after 60 minutes exposure to a hydrocarbon fire, as well as excellent ductility and toughness to withstand the design explosion.

Figure 1: Armada Platform Photo: Terry Cavner

Figure 2: Installation of final module aboard the Armada Platform

Design

The accommodation modules each measure 11.93 m long by 4.50 m wide by 3.20 m high and weigh around 23 tonnes. Both the accommodation modules and the two walkway modules had the same basic structural form: frame and stiffened flat plate floor and roof in carbon steel, overclad with corrugated stainless steel wall panels 250 mm wide, 80 mm deep and 2.0 mm thick.

The specified minimum 0.2% proof strength of grade 1.4401 stainless steel is 240 N/mm^2 [1], however, the mill certificates stated values in excess of 365 N/mm^2 and the design was based on these actual measured values. The main structural framing for the modules was made from carbon steel with a yield strength of 355 N/mm^2.

The modules have a fire resistance rating of H60 which means they must maintain their load-bearing function for a period of 60 minutes exposed to a hydrocarbon fire. A hydrocarbon fire reaches a temperature of 1100°C after 60 minutes. Austenitic stainless steels exhibit different strength and stiffness retention characteristics from carbon steel (Figure 4). Grade 1.4401 typically retains around 6% of its 0.2% proof strength at 1100°C [2], compared to carbon steel which retains only 3% of its yield strength.

The modules were designed to resist a peak blast pressure of 110 millibars with equal rise and decay times of 10 millisecs. Stainless steel is an ideal material for explosion-resistant structures because it has high strength, good energy absorption characteristics and high ductility [3]. The shape of the stress-strain curve in the plastic range ensures higher plastic moment resistance than carbon steel of equivalent strength. Stainless steels can therefore absorb considerable impact without fracturing.

H60 rated thermal ceramic superwool X607 insulation, which is sealed in an aluminium foil vapour barrier, was placed outboard of the primary carbon steel frame but inside the stainless steel panels to insulate the structural frame.

Figure 3: Single accommodation module at the Darlington factory

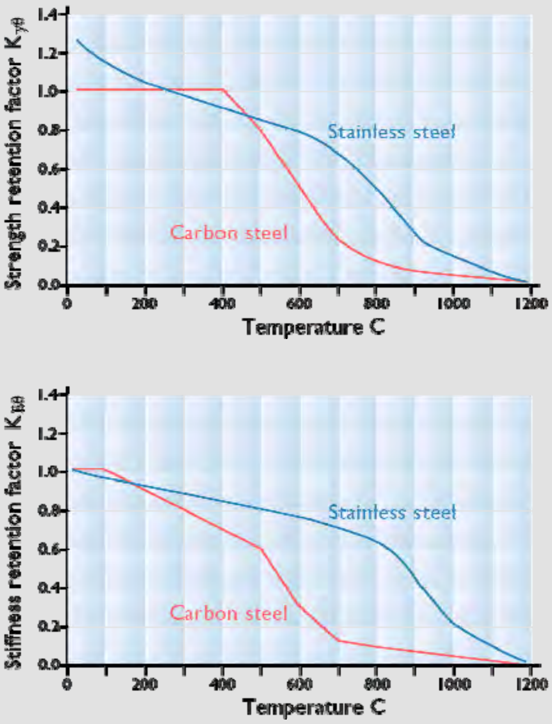

Figure 4: Comparison of stainless steel and carbon steel strength and stiffness retention factors (strength at 2% strain for both stainless and carbon steel)

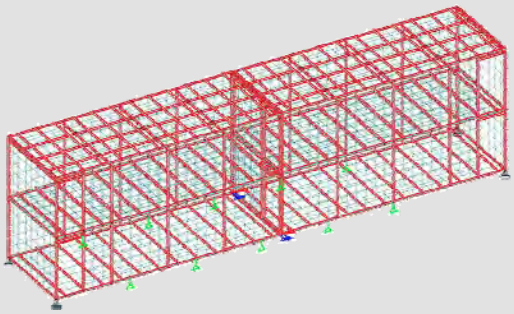

Figure 5: STAAD.Pro model of the framing members in the four accommodation units

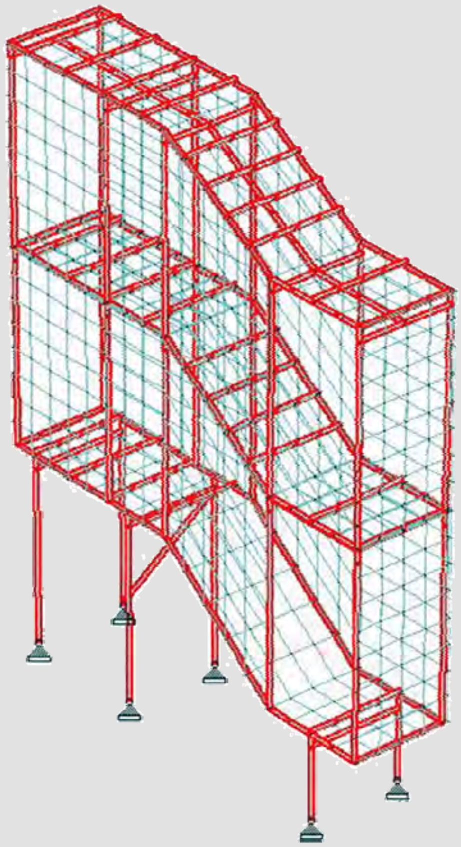

Figure 6: STAAD.Pro model of the framing members in a walkway module

Structural analysis

The structural performance of the modules under all the critical load combinations was analysed using the STAAD.Pro software. Two models were created for each of the accommodation and walkway modules: one for the H60 'hot case', with reduced material properties for the hot components in the structure; and a second for the 'cold case'.

Trapezoidal wall profiles are an economical structural form for withstanding transverse surface loads such as blast impulses. However, the complex shape of the profile could not be modelled accurately without undertaking time-consuming analyses. Therefore, using empirical representations and results from more detailed finite element analyses, effective equivalent orthotropic flat plate properties for the corrugated wall panels were derived which could be used in the STAAD.Pro models to model the bi-directional stiffness of the corrugated profile.

The design wind loading was taken as the 3 second gust 50 year return period equivalent to 1.68 kN/m^2 but conservatively taken as 2 kN/m^2. Snow and ice loading were also considered. The critical load combinations for the corrugated wall panels were:

– Dead and Live and maximum Wind (D+L+W)
– Blast

The models indicated that the maximum stress consistently occurred around the top and bottom edges of the modules, wherever a horizontal floor, roof or stair plate connected to a wall.

Fabrication

The 2 mm thick flat stainless steel sheets were supplied by a stockist. An in-house numerically controlled plasma cutter and cold press machine were then used to create and form the required profile. The stainless steel panels were prefabricated with the insulation and welded onto the structural frame. Welding of the carbon steel to stainless steel was performed using Metal Inert Gas (MIG) welding and continuously fed standard stainless steel electrodes with a gas shield (argon). After fabrication, the sheets were acid cleaned to remove any embedded iron particles which might rust when exposed to marine conditions.

Figure 7: Insulation placed inside the wall panels

Installation

The completed modules were transported by lorry to the coast, loaded onto ships and taken to the Armada Platform. Lifting pad-eyes were attached to the carbon steel frame at the 4 corners of each module through the cladding (Figure 9). The pad-eyes also doubled as shear guides for positioning the modules on the second level. The lower modules were attached to the module support frame (MSF) using stainless steel grade M16 A4-80 bolts.

The modules were connected together in a 2-on-2 formation with a provision for a third storey in the future. The stair modules were attached at either end (Figure 10) and sat on their own MSF.

Figure 9: Installation of an accommodation module

Figure 8: Accommodation module ready for transporting

Figure 10: One of the walkway modules connecting the new living modules to the original living quarters

Information for this case study was kindly provided by Mech-Tool Engineering.

References and Bibliography

[1] EN 10088-2:2005 Stainless steels. Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes.

[2] Design manual for structural stainless steel (third edition), Building Series, Volume 3, Euro Inox and SCI, 2006

[3] Design guide for stainless steel blast walls, Technical Note 5, Fire and Blast Information Group (FABIG), SCI, 1999

Online Information Centre for Stainless Steel in Construction:
www.stainlessconstruction.com

Procurement Details

Client: BG Group
Structural Engineer: Mech-Tool Engineering
Main contractor: Aiken Group
Steelwork contractor Mech-Tool Engineering

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