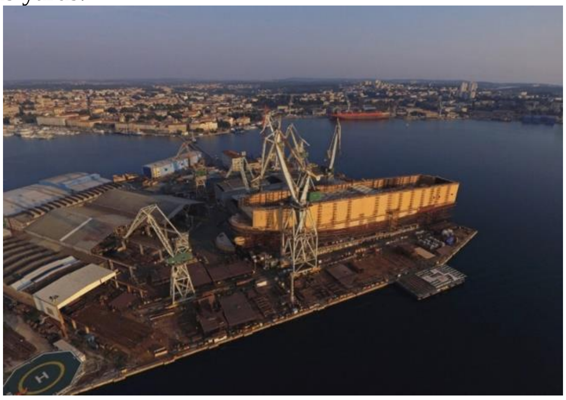
Technical Meeting — 3 April 2019

Valerio Corniani, Global Marine Segment Manager, Diab Group, gave a presentation on *Design of Car Decks with Composite Panels on a Car Carrier* to a joint meeting with the IMarEST attended by 47 on 3 April in the Harricks Auditorium at Engineers Australia, Chatswood.

Introduction

Valerio began his presentation by saying that his own background was in composites, mainly in the marine field and, especially, in small pleasure boats. However, in 2017 Diab received a request for the first case of a SOLAS-approved vessel, a car carrier. These vessels are basically big boxes with pointy ends, with lots of decks for transporting new cars from manufacturers to all parts of the world.

The Uljanik shipyard is in Pula, Croatia, was founded in 1856, and is one of the oldest operating shipyards in the world. The city has since grown around the yard, and the yard is now being squeezed for space. It is also facing stiff competition from overseas yards.



The Uljanik shipyard in Pula, Croatia
(Photo courtesy Diab Group)

The Project

The project actually started ten years before the first vessel was launched, with a European grant for research into how to save mass in the construction of ships. A bright young engineer on the research team came up with the concept of upper car decks constructed of composites. The first modelling on a ro-ro vessel predicted a deck structure mass reduction of up to 35%, a fuel-consumption reduction of 2% and consequent reduction of CO_2, stability benefits, and production and life-cycle cost reductions.

However, there was a question mark about the durability of composites under continuous car traffic. So they made up composite panels and placed them at the entrance the yard main carpark and subjected them to year of use without problems. With that question answered, the project continued to evolve.

Composite panel under test in carpark entrance
(Photo courtesy Diab Group)

Siem Car Carriers eventually placed an order for three car carriers from Uljanik, each to have the three top decks constructed in composites. Principal particulars of the vessels are:

Length OA		200.0 m
Length BP		188.7 m
Beam		32.26 m
Depth (upper deck)		32.12 m
Draft	(design)	8.00 m
	(scantling)	8.80 m
Dwt	(design)	13 370 t
	(scantling)	17 170 t

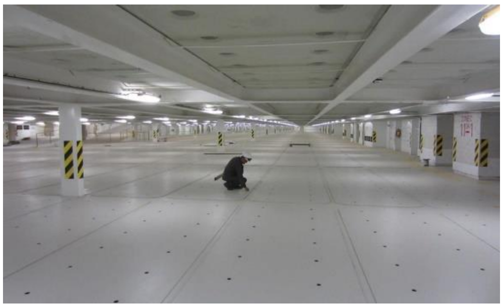
Capacity	7000 cars
Main engine	MAN-B&W 7 S 50 ME-B9.5 11 200 kW @ 117 rpm
Propulsion	Single screw
Speed	19.7 kn at 85% MCR and design draft
Flag	Liberia
Class	Bureau Veritas

The first vessel, *Siem Cicero*, was launched on 12 November 2016 and delivered for Volkswagen in July 2017 [*There is a video of the launch at https://www.siemcarcarriers.com/content_news/siem-cicero-launch-12th-november-2016/*—Ed.]

Siem Cicero
(Photo courtesy Diab Group)

Deck Design

Diab became involved in the supply of materials for the composite panels as they knew more than anyone else about sandwich composites. The view on a car deck looks similar to other car carriers, but with some differences: The decks have sandwich composite panels, supported by a steel grillage structure of girders and beams, with two rows of tie-down points in each panel.



Car deck showing composite panels, steel grillage and tie-down points
(Photo courtesy Diab Group)

The panels were designed with carbon and glass fibres either side of the 40 mm PVC core material, wetted out with resin. The fibres carry the tensile and compressive loads, and the core carries the shear load. The sandwich construction means that the structure can have thinner skins and be stronger and lighter than a single-skin layup.

Uljanik had good welders who handled the grillage structure, but they had no expertise in composites, so they sub-contracted the construction of the panels to the Croatian company Brzoglass. They constructed the panels by laying up the dry skins on a vacuum table, interleaved the foam core, applied the vacuum bag, connected the feed lines and pump. When the resin was fed in, it wet out the skins and provided high consolidation with no air bubbles. The process is called vacuum infusion. The edges were then trimmed to give the finished panel. Each deck has 2500 m^2 of 40 mm H80 core, and 1000 m^2 of 40 mm H100 core.. Each ship requires 1043 panels for the three decks; at 155 kg per panel, that's a total of 162 t per ship, a saving of 230 t over steel construction of those three decks.

However, the mass saving is not the only benefit. Since the mass saved is high up, the stability performance is improved by lowering the vertical centre of gravity, and so 575 t less ballast has to be carried, a total mass saving of 230 + 575 = 805 t. In addition, the fuel consumption has been reduced by 4.5% with a consequent reduction in CO_2 emissions for the same cargo capacity.

Panel Design

The panels had to be designed to meet the requirements of SOLAS, class, and the owner.

For SOLAS, there were the strength and fire-safety regulations to consider. Longitudinal and ultimate strength analysis was done without participation of composite panels, only the steel part was considered; i.e. the composite

panels do not contribute to strength in any way and the steel beams and girders ensure the integrity of the structure. Local structural design of beams was done to prevent any type of car from falling through the grillage to the next deck and thereby overloading. In summary, structural integrity is fully ensured by the steel members and the structure is therefore SOLAS compliant and equivalent to a conventional design.
For SOLAS fire safety, the composite decks are all within the same fire zone bounded by steel gastight structure, so there are no extra fire-protection requirements by SOLAS. The vessel is therefore SOLAS-compliant and conventional design procedures apply. There are no fire-retardant additives to the resin.
Bureau Veritas, the classification society, had no fire-safety requirements additional to SOLAS, and the structural requirements were according to BV rules. The composite panels were optimised by way of the number of glass fibre layers and fibre direction, and core type according to location (H80 and H100 both used). Finite-element analysis according to BV rules was completed.

Owner's Fire Safety
The owner came and said that the SOLAS fire-safety compliance was fine, but what about when loading cars alongside a berth—how good was the design? Uljanik therefore went to an independent company, the Technical Research Institute of Sweden (RISE) and asked them for a fire-safety assessment. The procedure of the analysis was based on the MSC/Circ.1002 *Guidelines on Alternative Design and Arrangements for Fire Safety*, even though all prescriptive requirements were considered achieved. Hence, the scope was not to achieve fire safety requirements in an alternative way but the methodology presented in SOLAS II-2/17 was used to demonstrate safety equivalent to that of a conventional steel design. The team conducted a preliminary analysis in qualitative terms, then did large-scale fire tests (on both steel and composite deck structures), conducted a quantitative analysis (18 FDS simulations were performed, varying fire growth rate, ventilation conditions, land/sea scenario, time to close vents, fire origin deck, and time for vertical fire spread for both steel and composites. They then analysed egress analysis and load-carrying capacity of the steel structure, and the risk of containment loss was evaluated based on these simulations.
They compared the spread of fire from one deck to another for steel and composite structures. They realised that the fire was able to spread between decks through the tie-down holes in the panels. They used the tests to model the rate of spread of smoke and fire, to determine how long people had to escape from the deck, and the last moment to activate the fire-suppression system. One benefit of the composite panels was that people struggle to walk on a steel deck which has a fire underneath because of the heat, but with composite panels with a 40 mm core, people can walk on the deck for a lot longer. The overall result that the first composite design was not as good as steel.
In the next iteration, they closed the underside of the tie-down holes in the panels which prolonged vertical fire spread, fire spread to the deck below was eliminated, and cargo lashing was functional for a longer time in a fire scenario. Automatic/remote-controlled dampers were provided, which gave fast-closing (immediately after alarm) and faster CO_2 activation. Position feedback was given on doors and dampers which allows crew to focus on failing doors and dampers, reduces risk of CO_2 activation despite failing doors and dampers. A30 insulation was provided below lifeboat embarkation stations, allowing safe lifeboat embarkation in case of uncontrolled fire in Gastight Zone C. The resultant comparison of the composite panels with the all-steel structure showed that the parameters for the composite panels were all better than steel except for the expected safety margin, which was above requirements in all cases. The owner was satisfied with that.

Fire safety assessment results
(Table courtesy Diab Group)

Criteria	Prescriptive design	Base design	TAD2*
PLL	0	0	0
Expected safety margin	20.5 min	13.5 min	13.5 min
Probability of structural integrity failure	12 %	51 %	3 %
Probability of loss of containment	10 %	10 %	1 %
Weighted average time to structural integrity failure	418 min	31 min	552 min
Weighted average time to containment failure	706 min	597 min	5973 min

In general, the composite structure delayed the spread of fire through decks, and allowed escape routes over the deck in case of a fire below deck compared to steel. However, there was increased fire growth rate, increased fire load, and toxicity from the burning resins and core.

Composite construction would not be easy to implement in cruise ships, which have the most strict fire, smoke and toxicity requirements. However, possible applications include bulk carrier hatches, and other commercial vessels.

Conclusion

In this innovative application of composites to the decks of a car carrier design, the deck structure mass was reduced by 230 t or 25%. Overall there was an 805 t mass reduction due also to the reduced amount of ballast required. Fuel consumption was reduced by 4.5% (2.1 t/day HFO) for the same cargo capacity. Production cost and lead time were reduced. There was improved safety of crew in case of fire below deck with respect to escape routes.

The end result was a SOLAS-compliant vessel with respect to fire safety, according to the SOLAS Conventional and Alternative Design Procedure. This was therefore the first extensive application of composites in a SOLAS compliant vessel.

Questions

Question time was lengthy and elicited some further interesting points.

The composite panels were bolted in place.

If there is such a mass saving from three decks, why not apply composites to all 14 decks? Further down, there is less benefit from mass saving, so more decks is not necessarily better. The design team considered that three decks was the optimum to start with.

The European grant justified the research at the start of the project to see whether the business case would stack up, and was done on the basis of the cargo decks of a Delight Transport ro-ro vessel, The research was based on four decks and predicted a 20% mass saving, so the business case was good.

The life expectancy of the vessel is unknown, but the life of the composite panels is expected to be at least that of the ship. Recycling the panels is a problem, because all are thermosetting and not thermoplastic. Being a mix of different materials, composites is by nature very hard to recycle

Valerio Corniani (L) accepting the “thank you” bottle of wine and certificate from Martin Renilson
(Photo Phil Helmore)

The vote of thanks was proposed, and the certificate and “thank you” bottle of wine presented, by the President of the Australian Division of RINA, Martin Renilson. The vote was carried with acclamation.