Research and Innovation
White Paper

MANAGING RISK DNV

Materials – SCS Sandwich

Use of Steel plate – Concrete – Steel plate Sandwich material in marine constructions

This is DNV

DNV is a global provider of services for managing risk. Established in 1864, DNV is an independent foundation with the purpose of safeguarding life, property, and the environment. DNV comprises 300 offices in 100 countries with 9,000 employees. Our vision is to create a global impact towards ensuring a safe and sustainable future.

Research and Innovation in DNV

The objective of strategic research is through new knowledge and services to enable long term innovation and business growth in support of the overall strategy of DNV. Such research is carried out in selected areas that are believed to be of particular significance for DNV in the future. A Position Paper from DNV Research and Innovation is intended to highlight findings from our research programmes.

Contact details:

Hege Berg Thurmann - Hege.Berg.Thurmann@dnv.com

Andreas Lervik - Andreas.Lervik@dnv.com

Hans Ramsvik - Hans.Ramsvik@dnv.com

Introduction

Marine vessels are today almost exclusively constructed by using stiffened steel plates structure. This has been the case for more than a century when steel took over from wood as the main construction material for marine vessels. Other materials such as concrete, aluminium, plastics, fibre glass and sandwich solutions consisting of different materials have been tried to some extent and used in special applications.

The reasons for steel being so recognized as a construction material for marine vessels are obviously due to the favourable material properties of steel with respect to strength as well as other parameters such as workability and durability. There are numerous possibilities for adjusting the structural properties by changing the steel material properties and construction arrangement. Furthermore, steel is readily available through local steel mills and dealers at competitive prices.

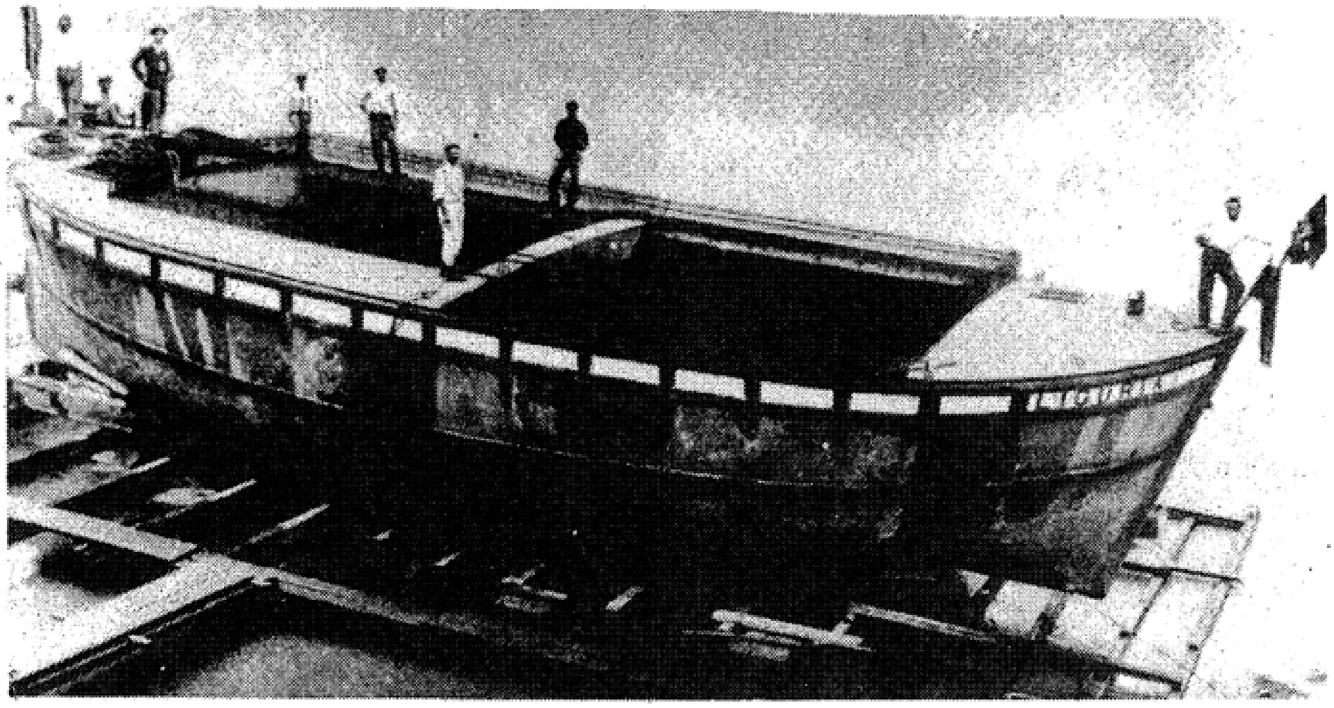
In this paper we will introduce the studies DNV has completed using a sandwich material consisting of Steel plate – Concrete – Steel plate in marine constructions.

Historic use of concrete in marine vessels

Concrete has mainly been used as construction material in marine vessels in periods of steel shortage or in constructions that are stationary for longer periods (e.g. oil production platforms).

Concrete vessels have been built according to traditional concrete building technology with the steel reinforcement located inside the concrete.

In 1917 DNV published "Preliminary Regulations for the Classification in Det Norske Veritas of Reinforced Concrete Vessels" and these regulations remained in force until the 1950's. Since this time almost no seagoing concrete ships have been built and there are no longer any DNV rules for concrete ships.



Barge built in Italy 1905 by Gabellini – 150 tons

Current challenges in marine constructions

Stiffened steel plates have a long tradition as a construction material for marine vessels. As material technology science, calculation methods and computer capacity have increased the ability to optimize construction scantlings we have experienced new challenges with steel as a construction material.

The factors that govern the main scantlings today are, in general: global bending strength, shear strength, buckling capacity and local strength.

Different vessel types and different areas of the vessel will have scantlings governed by one of these factors (e.g. the deck in the mid-ship area of bulk carriers is often determined by the buckling strength while the bottom area is decided by the bending strength).

Fatigue, corrosion, and local strength are the main areas where we today experience challenges which cost ship and oil rig owner's time and money.

Fatigue is normally experienced in local structural details, problem areas are now identified by advanced direct load calculations followed by FEM calculations and addressed by increased local scantlings and improved workmanship for the details. However, the detailed engineering work for FEM calculations and the improvement of local details are still not industry standard and we may experience fatigue issues for the foreseeable future.

Corrosion is well known in the marine industry and is today addressed by advanced coating systems and anodic protection systems or by adding corrosion margins as increases in the thickness of the steel scantlings to allow for the expected corrosion in the lifespan of the vessel.

Development of more corrosion resistant steel is ongoing and may be a solution for various applications.

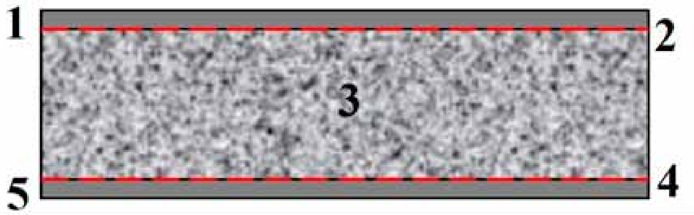
Local strength is related to smaller areas where the structure experiences higher loads than the design capacity. These high loads will normally be either transversal short term loads (causing indents) or axial forces (causing buckling). The reasons for these 'over load' forces are various (higher wave load, sloshing, poor loading, etc.) but commonly it requires greatly increased scantlings to avoid any possible overloading causing damages and therefore some local damages are commonly accepted as it is more cost effective to repair these periodically than to increase the scantlings to the necessary level.

The use of Steel – Concrete – Steels (SCS) sandwich materials in hull construction (either in combination with stiffened steel structures or for complete structures) may address these problems for some applications.

$$N \approx C\left(\frac{1}{\sigma \cdot K}\right)^3$$

Summary of the SCS sandwich studies

In about 2000, DNV came up with the idea to use steel-concrete sandwich (SCS) as construction material for marine vessels.



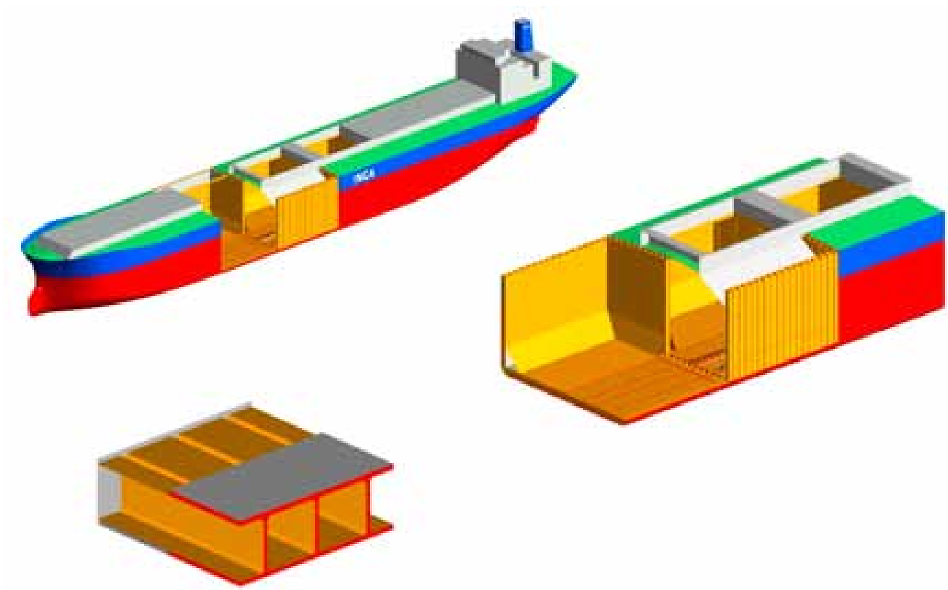
1 & 5: Steel plate

2 & 4: Bondline between steel plate and core: adhesion of concrete to steel.

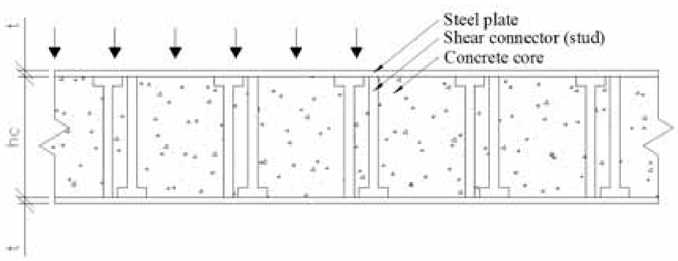
3: Core: lightweight concrete material

The concept is to use a composite of a steel sheet – light weight concrete – steel sheet to replace steel plate and secondary stiffener structures. The idea was initially developed to address safety issues with bulk carriers and the abbreviation INCA originates from an **IN**novative Bulk **CA**rrier design.

Since then, DNV has been working to explore the possibilities and potential for the SCS concept together with a large shipyard group and other industrial partners. The concepts were granted patents in a number of countries. A new project was initiated in late 2009 to assess the technical feasibility of using INCA in marine vessels. The project's focus was on exploring the commercial potential of the INCA sandwich technology for use within the marine industry and to identify a way forward for possible industrialisation of the technology. This included also a recommendation on whether to maintain the current patent portfolio which was originally taken to avoid other industry stakeholders from blocking the broader development of SCS sandwich structural solutions.



From the technical assessment in the latest study it was concluded that the original INCA technology (without shear studs connecting the face plates to the core) requires further research before it can be used. However, by using shear studs or pins, and established industry practise for concrete steel composite design the technology can be developed into practical solutions for structure in ships and offshore structures.



The material properties used for the latest study were based on today's available materials and, from this work, it seems that INCA is best suited to solutions which are not weight critical and where other benefits of the technology can be utilised to offer additional advantages.

The focus so far has mainly been on using sandwich panels in parts of a conventional steel structure and it is believed that the full potential of SCS structures can only be realised by designing complete structures, such as floating barges or ships, where the overall arrangement makes the best use of the properties of the INCA concept rather than just replacing members in an optimised steel design with INCA panels.

For such structures it is assumed that SCS can be constructed locally, using local materials and labour.

From the perspective of DNV it was concluded that the greatest potential for further successful development of the INCA technology is to encourage industrial partners to explore the potential of applications where INCA offers advantages compared to normal steel construction methods. Therefore, DNV have released all the INCA patents, enabling all interested parties to pursue the technology further, without any contractual issues arising from the patents.

Further work for DNV should be based on commercial terms with interested parties and could include assistance with technology qualification, verification and classification.

It was further concluded that, despite the fact that INCA panels do not seem to be all that competitive for ocean going ships, there are many other opportunities for use of concrete in marine applications for short sea shipping and river transportation. It was also noted that DNV's technology qualification process is a most efficient approach to the qualification of new technology - the more innovative the technology is the more critical it is to manage the qualification according to this process.

Potential for using SCS Sandwich material in marine constructions

The principal advantage of using steel-concrete-steel (SCS) sandwich structures is the reduction in the number of traditional structural elements and replacing them with cheaper concrete as part of a simple layered structure. The resulting structure is flat on both sides reducing maintenance costs; for example by reduced coating, inspection and insulation; and offers low heat conductivity and improved resistance to impact and maltreatment.

For smaller ships and offshore structures a one-shot build could be imagined where thin steel formwork can be easily shaped to make the hull, held apart by connecting studs, and filled with concrete to complete the SCS structure. Techniques exist for such large scale concreting within the building industry. Once larger structural units (or complete ships) are considered it is also possible to leverage even more benefits from the concrete industry, examples include post-tensioning of the structure to improve the performance of the concrete part of the structure, and tuning of the type of concrete used along with associated construction process to suit local material availability, expertise and construction methods.

Through this optimisation of the design and construction method the weight penalty associated with SCS structures when used in place of small parts of a ship or offshore structure may be reduced or possibly eliminated. Hence, the following areas are examples of potential areas for profitable exploitation of the technology in the near term:

1. Simple stationary floating structures, e.g. a large floating oil storage barge.

2. 'Brown Water' ships (e.g. river craft or inshore cargo ships) designed and optimised for complete construction in SCS or traditional re-enforced concrete.

3. Structures for use in cold climates (making best use of the low temperature conduction properties of concrete).

4. Linked to the above, barges for LNG transportation

5. Blast resistant structures and heat boundaries on existing offshore structures, e.g. FPSO Process Decks.

6. 'Damage tolerant' structures. E.g. for fendering on offshore platforms or for berthing pontoons subject to impact loads.

7. Vessels where weight is not a critical factor (e.g. vessels that require permanent ballast for stability).

Qualification of new technology

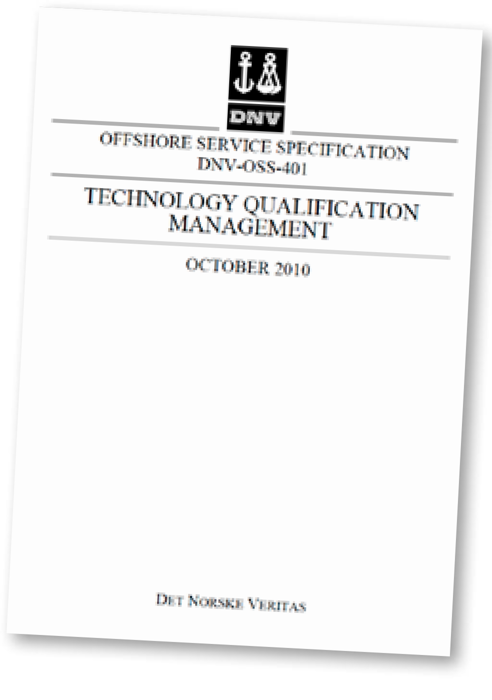
The DNV technology qualification process and associated services aim at assisting in building and operating new technologies in a financially sound, safe, reliable and environmentally friendly way.

DNV developed the first, industry-recommended practice for qualifying new technology – the DNV-RP-A203 'Qualification Procedure for New Technology'. We combine risk management expertise with extensive knowledge of the industry's technologies. Since DNV is an independent company working with both operators and technology vendors, we have accumulated great insight into most of the industry's failure modes and mechanisms. This knowledge base makes DNV a unique partner for qualifying technology and improving its reliability and performance.

DNV's technology qualification differs from typical third-party services such as classification, certification, and verification, which basically confirm that the technology is in compliance with specified codes and procedures. Qualification, however, is defined as the process of providing the evidence that the technology will function within specific limits with an acceptable level of confidence.

Usually, a new or improved technology can either enable a project to be realized or it can enhance its value. Either way the developer has to build the operator's confidence in the technology. Further, the operator needs to ensure that the other stakeholders in the project also are confident before a decision to implement the technology can be taken. This requires a systematic risk-based qualification process that clearly documents the performance of the technology.

Unfortunately, qualification of new technology developments is often done as an afterthought and sometimes it does not provide all the evidence needed to prove that the technology will function as intended. Failure modes and mechanisms may not have been systematically identified by multi-disciplinary teams and appropriately risk ranked. Large expensive tests may have been performed without a clear understanding of what failure modes the test simulates and the margin to the failure envelope. The simulated operating condition may not have been representative of the actual operating condition. Analytical models may not have been used to predict the failure mechanisms. These are some of the issues that can prevent the end user from gaining the required confidence in a technology and that can be overcome by using an established qualification procedure and involving the relevant expertise in the process.


OFFSHORE SERVICE SPECIFICATION
DNV-OSS-401

TECHNOLOGY QUALIFICATION MANAGEMENT

OCTOBER 2010

DET NORSKE VERITAS

DNV concrete and sandwich technology competence

Since the "Preliminary Regulations for the Classification in Det Norske Veritas of Reinforced Concrete Vessels" was issued in 1917 to now, DNV has focused on competence and knowledge within concrete material technology.

Concrete material has been used in the ocean for generations and is a material suitable for the marine environment. Major offshore concrete structures (fixed and floating) have been constructed for the oil industry since the early 1970's.

More recently, reinforced concrete has been successfully applied in offshore wind turbine foundations. Having been involved in many offshore concrete platform projects, ports and terminals and offshore wind turbine projects, DNV has wide experience with the different aspects of concrete material in the marine environment. Reference is made to the Offshore Standard DNV-OS-C502 "Offshore Concrete Structures", addressing design of concrete structures in a marine environment

In order to support the global energy and shipping sectors with state-of-the-art laboratory services, DNV offers a wide range of testing capabilities, combined with strong multi-disciplinary knowledge and experience. DNV's laboratories are located in Oslo and Bergen in Norway, Singapore, Kuala Lumpur in Malaysia and Dublin, Ohio in the USA.

Further information

Reference to the external version of the INCA technical report

Please contact your local office or section for Technical Advisory Ship and Offshore for Concrete Structures – Hege.Berg.Thurmann@dnv.com / Andreas.Lervik@dnv.com or by phone +47 6757 9900

Det Norske Veritas
NO-1322 Høvik, Norway
Tel: +47 67 57 99 00

www.dnv.com

Design, layout and print production: Erik Tanche Nilssen AS, 05/2011
Printed on environmentally friendly paper.