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Experimental investigation of Steel–Concrete–Polymer composite barrier for the ship internal tank construction

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A B S T R A C T

Transportation of dangerous cargo by ships demands ensuring an appropriate protection level in case of an accident. Two of the most dangerous accident types resulting in an oil spill are grounding and ship to ship collision. The article presents results of research on a new composite construction for a ship hull that increases structural safety during collision. The concept of semi-elastic Steel–Concrete–Polymer structure is presented. The most important results of the research are discussed. The resistance to collision and grounding of the new sandwich solution is investigated by means of two independent large scale experiments. The first collision experiment was conducted on a reference ship section representative for a double bottom or a double side of a ship. The second test was performed on a construction similar to the first one, but with an additional semi-elastic protective barrier. Both ship sections were loaded in the same manner by a sphere-shaped intender simulating the assumed collision scenario. On the basis of large-scale collision experiments the new solution of semi-elastic protective barrier was proven to significantly increase resistance to collision and grounding.

1. Introduction

The need of risk reduction during transportation of hazardous cargo brings new kinds of solutions to the structural design of ships and offshore structures. Since late 1950's greater crashworthiness was achieved mainly by redesigning the conventional structure. Many independent researchers proposed to redesign the single and double shell of a ship hull with the goal of increasing energy absorption during collisions i.e.: Kitamura (1997), Wevers, Vredeveldt (1999), Kim and Lee (2001), Klanac et al. (2005a, 2005b), Ehlers et al. (2007), Hong et al. (2007) and Tavakoli et al. (2007). Some of the ideas included changing the form of damage by weakening the connection between girders and shell plates (Tautz 2007). During a collision the inner shell of the hull intentionally separates from the web and enables large deformation of the structure. Increasing safety by keeping the tightness of the inner shell was also evaluated (Karlsson, 2009). The structure redesigned in such a way so as to enable large plastic deformation of the inner shell remained tight at 2 times deeper penetration by the striking ship. Other similar examples can be found in Ringsberg et al. (2010). A different solution, the so-called bulbous bow, concerns redesigning the ship bow to minimise effects of the collision (Yamada et al., 2005, 2006). The general idea is to design a weaker bulbous bow, which results in protecting the ship being hit from damages. Research on increasing energy absorption by the bow is still under progress (Tautz et al. 2013). Moreover, in the last 15 years some new alternative solutions were introduced bringing significant improvements. In fact the most advantageous structural concepts were designed with respect to achieving increased collision resistance. Laser-welded X and Y-shaped structures were developed and tested in a natural scale (Peschmann, 2000; Wolf, 2003; Tabri et al., 2004). The sandwich solution enables a significantly greater collision resistance in comparison with the standard design. This concept was analysed in 10 geometrical alternatives to identify the potentially most promising solution (Klanac et al., 2005a, 2005b). The research conducted with the use of FE simulations pointed that one variant can absorb 40% more energy in comparison with the conventional double side. Other research works performed on X-corrugated steel panels showed that filling the free volume inside the panel with a lightweight concrete increases the dissipation of the collision energy by about 10% (Törnqvist, 2003). Some of the new concepts involve different materials for redesigning a ship structure. Research on INCA panels showed that for certain applications steel–concrete–steel panels may be beneficial (Weitzenböck and Grafton, 2010). Unfortunately resistance to collision and grounding was not analysed for this type of structure. The technology is very promising, especially if a much lighter core material would be found. Other research project examined the collision resistance of ship structure stiffened with trapezoidal profiles filled with lightweight concrete (Röhr, 2008). In comparison with the standard design this solution offers about 40%

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increase in capturing the collision energy. Another researcher used foamed polystyrene blocks as the filling of a double-shell structure (Kulzep, 2001). Experimental results showed a 32% increase in energy absorption in comparison with an analogical empty structure. Other interesting idea (Schöttelndreyer et al. 2013) was based on filling the side structure with special granulate material (glass spheres). The presented results showed that this solution can absorb about 76% more energy than the reference one. A significant advantage of this idea is that it adds only 26% to the structure weight. The latest publications present capabilities of a steel–polymer–steel composite structure with respect to a collision scenario (Notaro et al., 2013). It is an overlay system consisting of a 40 mm lightweight core and a 20 mm steel top plate which can be added on the standard design. It was found that the increase in stiffness raises the impact resistance about 2 times.

In this article a new conceptual Steel–Concrete–Polymer composite design is presented. The idea is to add a semi-elastic protective barrier to the standard ship structure.

2. Steel–Concrete–Polymer (SCP) sandwich construction of a ship hull

The new composite construction of a ship hull is introduced to assure greater safety in case of collision and grounding accident. The SCP construction increases the crashworthiness of a ship

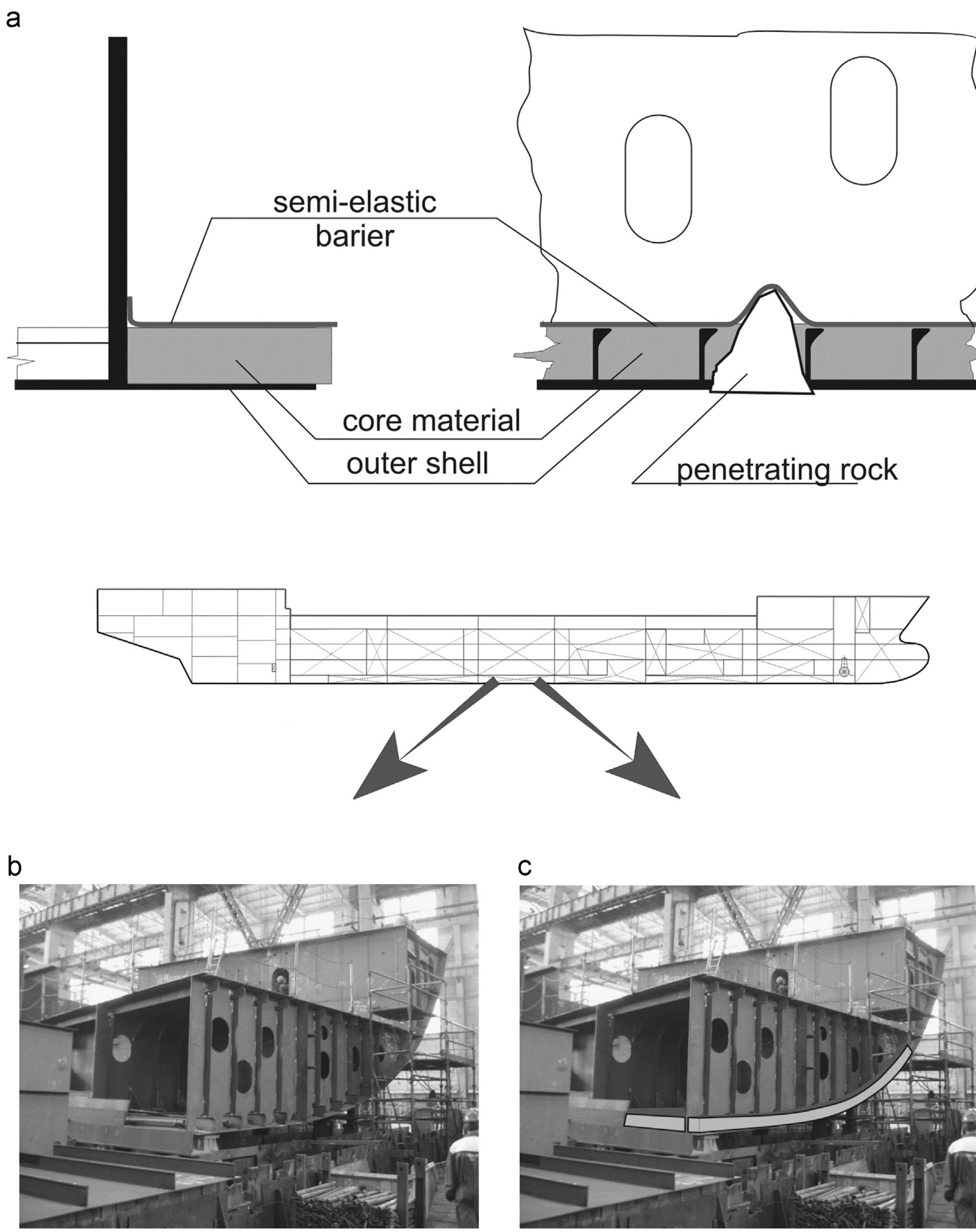

Fig. 1. General idea of the additional semi-elastic protective barrier (a), typical single-skin bottom-tank construction (b), possible location of the additional semi-elastic barrier (c).