Sandwich Core Material Development for Ship Deck Structure

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***Abstract* - Development of sandwich materials for ship structure is aimed mainly to reduce the ship light weight so that the ship payload increases. This paper addresses development of sandwich core material suitable for ship structure. The core materials were composed of synthetic resin and talc; percentages of talc by total weight investigated were 10%, 20%, 30%, and 40%. Laboratory tests stipulated by the Lloyd's Register (LR) and Det Norske Veritas (DNV) were performed on the core materials. Moreover, sandwich plates consisted of steel faceplates and the core materials were tested using ASTM standards including tension, shear, and flexure tests. The sandwich plates were applied for designing car deck of a ro-ro ship. Analysis of the sandwich deck under design load utilizing finite element approach was carried out to select the best sandwich core materials developed in this study. It was observed that the sandwich panel deck composed of synthetic resin and core material with 40% talc was better than the others.**

Keywords: Sandwich Structure, Synthetic resin based core material, Ship deck

I. Introduction

Sandwich structure is consisted of two different types of materials, i.e., faceplate which is stiff in bending and core material which is usually lighter and less stiff than the faceplate. Application of sandwich materials for ship construction were studied by Utomo and Baidowi and Utomo el al. [1][2]. Utomo and Baidowi [1] studied sandwich plates consisted plywood faceplates and three different core materials, viz., polyurethane, poly resin, and synthetic resin. These materials were chosen because they were easy to find and relatively cheap. The results of their study showed that the sandwich structure could be applied for ship construction. Utomo et al. [2] reported development of sandwich plate constructed using steel faceplate and synthetic resin core material. Flat plates of a ship were designed using the sandwich plate. It resulted in reduction of the ship's light-weight by 13%. This paper presents results of study on further development of synthetic resin based core materials for sandwich plate structure of ship. It aims at investigating the sandwich plate densities and strengths for different core material compositions. In addition, their effects on the stresses developed on the sandwich plate under design load were examined when a ship deck was designed using the sandwich structures.

II. Method

In this study the core materials were developed and tested to meet Det Norske Veritas (DNV) [3] Lloyd's Register (LR) standard [4]. Figure 1 shows diagram of sandwich plate development and the sandwich plates' application to ship deck. The process started from identification of core materials. The core material consisted of synthetic resin and talc with varied weight; The talc was 10%, 20%, 30%, and 40% of the core weight. To make the core material dried faster catalyst was added. During the process of fabrication and cutting core materials might be cracked or even broken into pieces. Therefore, the process ought to be conducted carefully. Moreover, monitoring of the temperature during the reaction process needed to be carried out so that facture happened on the core material could be avoided. The core materials properties had to meet standard assigned by DNV and LR [4]. Therefore, the core materials were tested in the laboratory for obtaining e.g., material density, tensile strength according to ASTM D412 [5] and shear test of ASTM C273[6]. When the core material properties were met the standard sandwich plate could be fabricated. Samples of the sandwich plate were then tested following procedure stated ASTM C393 [7]. The sandwich plates were applied to design ship deck structure. The results of these analyses were utilized to select the best composition of core materials investigated in this study.

III. Results and Discussion

A. Identification of core materials

As mentioned earlier, four different core material compositions were fabricated; they were named core material A, B, C, and D. Core material A was composed of 10% talc and 90% synthetic resin, core material B was composed of 20% talc and 80% synthetic resin, core material C was made up of 30% talc and 70% synthetic resin, and core material D was made up of 40% talc and 60% synthetic resin. Tests were conducted on these core materials including density, tensile, and shear tests. Five samples were prepared for each test. Average values of these tests are presented in Table 2. The densities of core materials A, B, C, and D were met the DNV criteria which stipulates that it must be larger than 1000kg/m3.

Tensile strength, modulus of elasticity, and shear modulus of core materials A, B, C, and D were obtained from the tensile and shear tests, see Table 2. Table 2 shows that compared to other core materials, the density of core material A was the lowest but the core had the highest tensile strength. Core material D had the highest modulus of elasticity but it had the lowest tensile strength. It seems that the talc made the core material more rigid and the tensile strength lower. Tensile strengths and tensile modulus of the core materials were larger than those required by LR and DNV. Shear modulus of core material A was less than that requires by LR and DNV even though its density was smallest among the core material develop for this study.

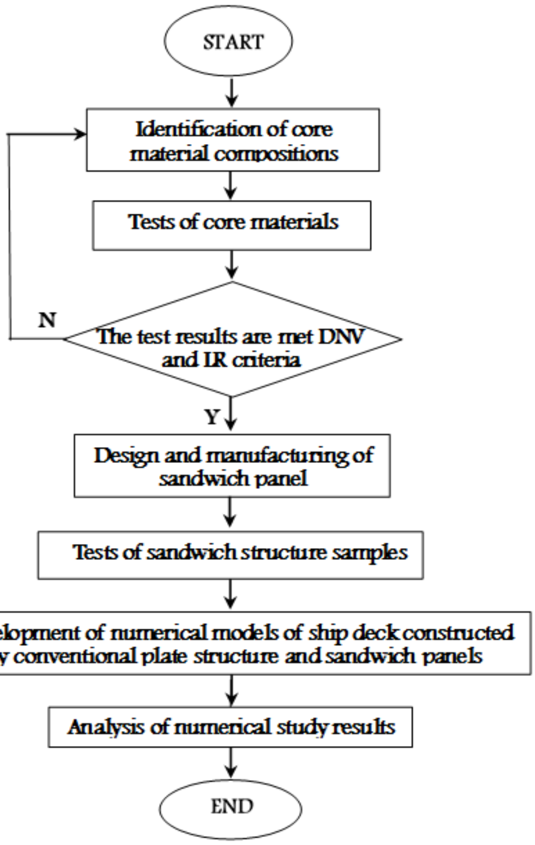

Figure 1. Diagram of Sandwich Panel Development and Application to Deck Structure of Ship

Table 2. Properties of core materials developed in this study

Core Materials	**Density (kg/m^3)**	**Tensile strength (MPa)**	**Tensile Modulus (MPa)**	**Shear modulus (MPa)**
Core Material A	1184	22.83	254.65	110.86
Core Material B	1354	21.75	307.17	121.28
Core Material C	1409	20.64	325.43	135.00
Core Material D	1501	20.04	333.55	144.17

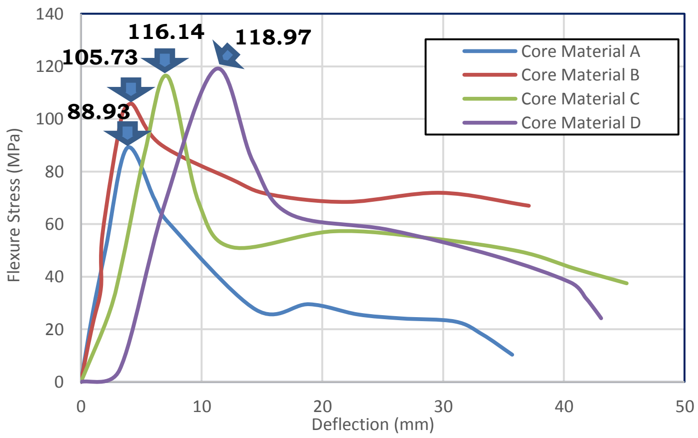

Figure 2. Flexure stress vs deflection diagram of sandwich plates constructed using core materials A, B,C, and D

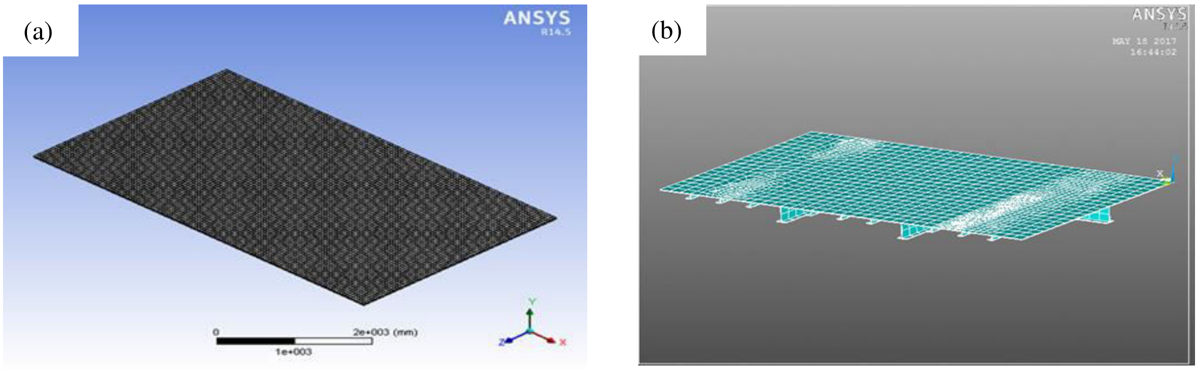

Figure 3. Finite Element models of (a) Sandwich panel deck, and (b) Conventional plate deck

B. *Flexure test of Sandwich Plate Samples*

After the core materials were identified sandwich plates were fabricated and tested under bending test. The sandwich plate thickness was 32mm; it had 20mm thick core and 6mm thick top and bottom steel faceplates. Flexural test using ASTM C393 standard [7] was performed on the sandwich plate samples to determine the characteristics of the sandwich plate material and the results are presented in Figure 2. The figure shows flexure stresses and deflections obtained from the tests for sandwich plate having different core materials. The ultimate flexure stresses of sandwich plates under the loads are also presented in the figure.

As seen in Figure 2 during the test sandwich plate structure with core material D had higher maximum stress than those of other core material compositions. It seemed that larger amount of the talc material made better stiffness and strength.

C. *Application to ship deck structure design*

The sandwich plate structure was applied for redesigning car deck of ship. It was the deck structure of 750 GT Ro-Ro passenger ship. The deck was 6000 mm long and 3500 mm wide. It was constructed by applying conventional steel plate construction. A36 steel with ultimate strength of 235 MPa was used for the ship deck construction. The deck was redesigned utilizing 32mm thick sandwich plate developed in this study. ANSYS finite element analysis software was utilized for this purpose. Finite element models for sandwich panel deck and conventional stiffened plate deck were developed, see **Figure 3**. Stresses of the decks under local design truck load of 100kN were computed using the software. The load was distributed and located so as to represent wheel truck loads on the ship deck. Stresses under the load for deck of the sandwich panels A, B, C, D and in conventional plate are presented in Figure 4. Sandwich panel A was sandwich plate deck structure consisted core material A and steel faceplates. Similar terminology was applied for sandwich panels B, C, and D.

Table 3 presents that maximum bending stress of the ship deck constructed by conventional plate and the sandwich panels under the design load. Stress ratio which was defined as the maximum stress under the load divided by the ultimate stress is also presented in the table. The stress ratio values suggested that the sandwich panels could withstand the design load. The stress ratios of the sandwich panel were slightly higher than that of the conventional plate structure. The panel D was better than the other sandwich panels however.

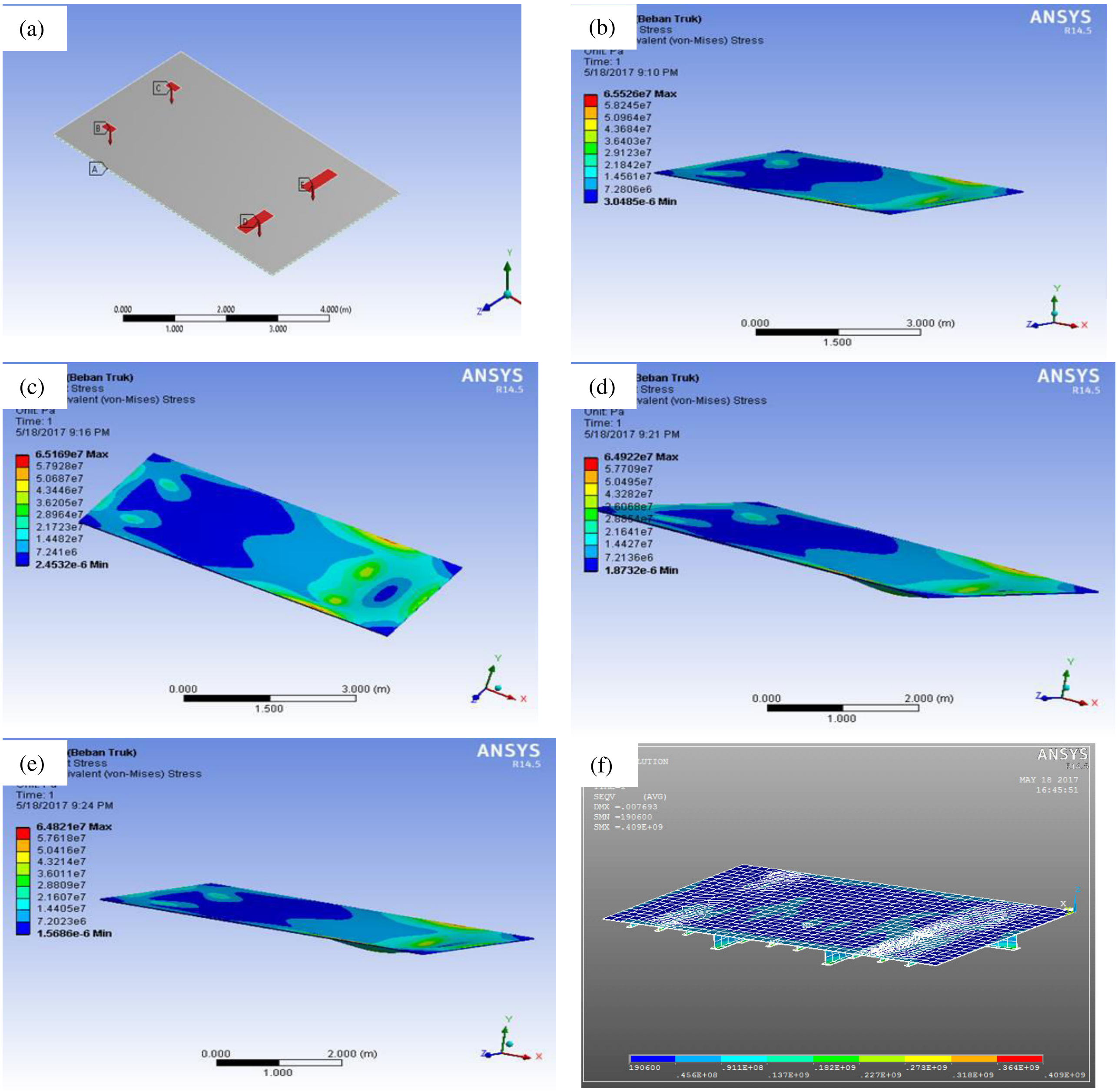

Figure 4. (a) Load locations on the ship deck; Stresses occurred on the deck of (b) Sandwich panel A, (c) Sandwich panel B, (d) Sandwich panel C, (e) Sandwich panel D, (f) Conventional plate

Table 3. Comparison of Bending Stress of Sandwich Panels and Conventional Steel Plate Construction

Ship Deck Structure	Max Bending Stress (MPa)	Stress ratio*
Sandwich Panel A	65.52	0.737
Sandwich Panel B	65.15	0.616
Sandwich Panel C	64.92	0.559
Sandwich Panel D	64.82	0.545
Conventional Plate Construction	81.81	0.348

* the ratio is equal to max bending stress divided by ultimate stress, see Fig 2 for sandwich panel ultimate stress

IV. Conclusion

This paper discusses development of sandwich plate core materials of ship deck structure. The core materials and sandwich plates were tested according to ASTM standards. Deck of a ro-ro ship was redesigned using the sandwich plates with cores developed in his study. Finite element analysis was performed to obtain stresses on the sandwich deck panels under design load. The results showed that sandwich deck panels with developed core materials were applicable for ship deck structure. However, maximum stress occurred on sandwich deck panel consisted of core material which composed of 40% talc and 60% synthetic resin was lower than other compositions studied in this paper.

V. ACKNOWLEDGMENT

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