Project A: Analysis of a stiffened plate panel

The figures below show a car deck panel in the RoRo car ferry Prins Richard.

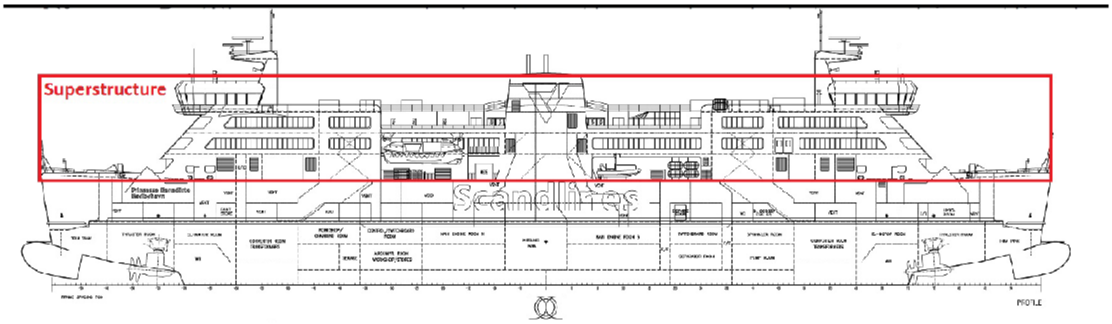
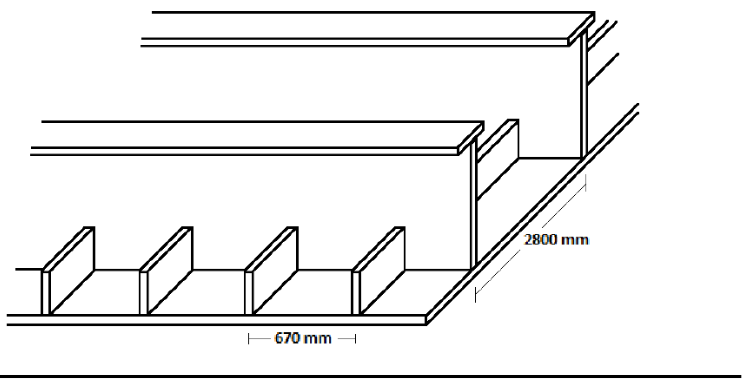


Figure 1: Prins Richard in profile with the superstructure marked in the red box.



The car deck is 55.8m long and 9.95m wide. The thickness of the deck plate is 6.5 mm. The deck is not supported by columns inside its extension, but only supported along its boundaries by columns and bulkheads.

The car deck is stiffened with longitudinals (flat bar 160x12 mm) spaced 670mm and transverse beams (T-profiles: web 690x10mm, flange: 100x10mm) spaced 2800mm.

Steel: $E = 2.1 \cdot 10^{11}$ N/m^2
$\nu = 0.3$
Density $\rho = 7850$ kg/m^3
Material yield stress: $\sigma_y = 250$ MPa

In the design of the deck panel it is necessary to check the stiffness and the strength with regards to:

- Lateral loads: These are uniform loads (from a distribution of cars and trucks) and more concentrated loads from heavy trucks. The lateral loads may cause permanent deformations and rupture in the plating.
- In-plane loads: From the global bending of the ship hull girder. The in- plane loads may lead to buckling of the plating, which in turn may lead to global collapse of the hull girder.

In the project you will analyze first a separate sub-panel of the car deck plate panel (Part A), and later you will analyze the entire stiffened car deck panel both analytically and numerically using FEM.

The report should not have a length longer than 25 pages in total. Appendices are allowed, but will not be directly included in the evaluation of the report.

Given the limited number of pages of the report, be critical with the amount of plots and illustrations you choose to include in the report, and present your results in a precise and concise manner, eg. in terms of compact tables with results.

The percentage given for each question is an indication of the maximum percentage the particular question constitutes of the total evaluation of the project.

41517 Stiffened Plates and Sandwich Constructions
Project A: Analysis of a stiffened plate panel
Submission Deadline: Tuesday 27/03/2022 at 16:00

Part A: A Single Plate Element

The considered steel plate has the following characteristics:

- Length a = 2800mm,
- Width b = 670mm,
- Thickness t = 6.5mm

Question A.1 (5%): What is real life plate structures?
This is an in-field exercise to locate and document plate structures in your daily surroundings. Take pictures and describe what you see, and include your findings and discussion in the introduction to Project A.

Question A.2 (5%): What type of boundary condition is the most appropriate?
In other words: should the plate be considered simply supported, clamped or with a combination of the two along the boundaries? Your answer probably requires some discussion regarding type of analysis (static loading or buckling) as well as loading type.

Question A.3 (5%): Which analysis methods are available and most useful? The course has presented the two solution methods:

1. Direct solutions to the governing differential plate equation
2. Energy methods (Rayleigh-Ritz)

Your answer probably requires some discussion regarding the assumptions for the boundary conditions and load variation. Also the degree of accuracy and the results of interest (stresses or deformations) might influence your answer.

Question A.4 (10%): Calculate the deflection and the maximum stresses due to a uniform static pressure load.
Assume that the plate is simply supported and that the load is uniformly distributed with a pressure equal to 10 kN/m^2.
Calculate the deflection in the center of the plate and the maximum stresses (direct, shear and v. Mises) by use of Navier's method and the energy method (assume linear, elastic behaviour). Use the energy method to solve the same case with more appropriate boundary conditions. Compare the results and discuss any differences. Show only plots of deflections and v. Mises stresses.

Question A.5 (10%): Calculate the deflection and the maximum stresses due to a concentrated static load.
Assume that the plate is simply supported and that a load of 20 kN is concentrated on an area of 200mm*250mm at the center of the plate. Calculate the deflection in the center of the plate and the maximum stresses (direct, shear and v. Mises) by use of the methods discussed above (assume linear, elastic behaviour). Use the energy method to solve the same case with more appropriate boundary conditions. Compare the results and discuss any differences. Show only plots of deflections and v. Mises stresses.

Question A.6 (10%): Calculate the buckling load.
Assume that the plate is simply supported. Calculate the lowest buckling load for a uniform in-plane load by use of two methods. Use the energy method to solve the same case with more appropriate boundary conditions. Compare the results and discuss any differences.

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Part B: A Car Deck Panel

The plate panel has the dimensions 9.95 x 55.8m and can be assumed simply supported along all four sides.

Question B.1 (15%): Calculate the uniform lateral pressure resulting in yielding of the outermost part of a stiffener.
Hint: Use orthotropic plate theory and apply the maximum bending moment to a stiffener/longitudinal (see example pp 37-40)

Question B.2 (15%): Calculate the lowest buckling stress for the plate panel and its individual elements.
The in-plane loading is in the direction of the longitudinal stiffeners and uniform over the panel width (9.95m). Discuss whether the panel needs redesign and, if required, suggest changes of thicknesses (of plate and stiffener components) that preserve the total weight of the panel and re-calculate the buckling strength.
Hint: Use orthotropic plate theory for the whole panel and isotropic plate theory for the individual components: deck plate, stiffener flange and stiffener side. Remember to include tripping as a failure mode in the calculations for the ship panel.

Question B.3: Redesign with fewer T-bar stiffeners. (OPTIONAL – not in lectures)
The original panel is redesigned in an attempt to make a simpler design with the same weight by removing half of the T-bar stiffeners and increasing the dimensions of the remaining to (in mm): d/f x h_w/h_f =690/100 x 10/15, i.e. increasing the flange thickness. Calculate the collapse in-plane load of the panel. What is the reserve strength, i.e. the load increase from initial buckling of the plate between the stiffeners to collapse? Is the redesign feasible? (i.e. reconsider Questions A.4 and A.5).
Hint: Use the energy method for the orthotropic plate with the transverse stiffeners added as single beams.

Part C: FEM Analysis of Single Plate Element and Car Deck Panel

Question C.1 (20%): Apply FEM to analyze plate elements and the entire car deck panel.

FEM analysis of the single plate element and the car deck panel should be carried out. You need to select one of the tasks in Part A from A4-A6 and another one in Part B from B1-B2 for FEM analysis. Compare and discuss your results with the analytical solutions.

Question C.2 (5%): Reflect and discuss on the differences between orthotropic plate theory and realistic representation of all stiffeners in a plate panel analysis, eg. using FEM.