Numerical Simulation of Boundary Layer Flows Around Simplified Subsea Structures

Dennis Alexander Nymo (dennisnymo@gmail.com)

Supervisors: Prof. Dag Myrhaug, Dr. Muk Chen Ong & Leiv Aspelund (Subsea 7)

NTNU – Trondheim Norwegian University of Science and Technology

subsea 7

Motivation

Glass reinforced plastic (GRP) covers are used to protect subsea equipment such as pipeline connection points, spools and umbilical control connections close to the subsea templates from dropped objects and fishing gear. GRP is the material of choice for these covers as it is competitive compared to steel in terms of corrosion resistance, fabrication and installation weight. Figure 1 illustrates GRP covers during installation on seabed. GRP covers has a weight which is one third of equivalent covers in steel, hence more likely to move due to forces induced by water currents and wave induced velocities. To find the forces involved, experiments or numerical simulations are necessary. It is hard and expensive to achieve high Reynolds number flow conditions in laboratory testing, hence Computational Fluid Dynamics (CFD) is an attractive alternative for engineering design.

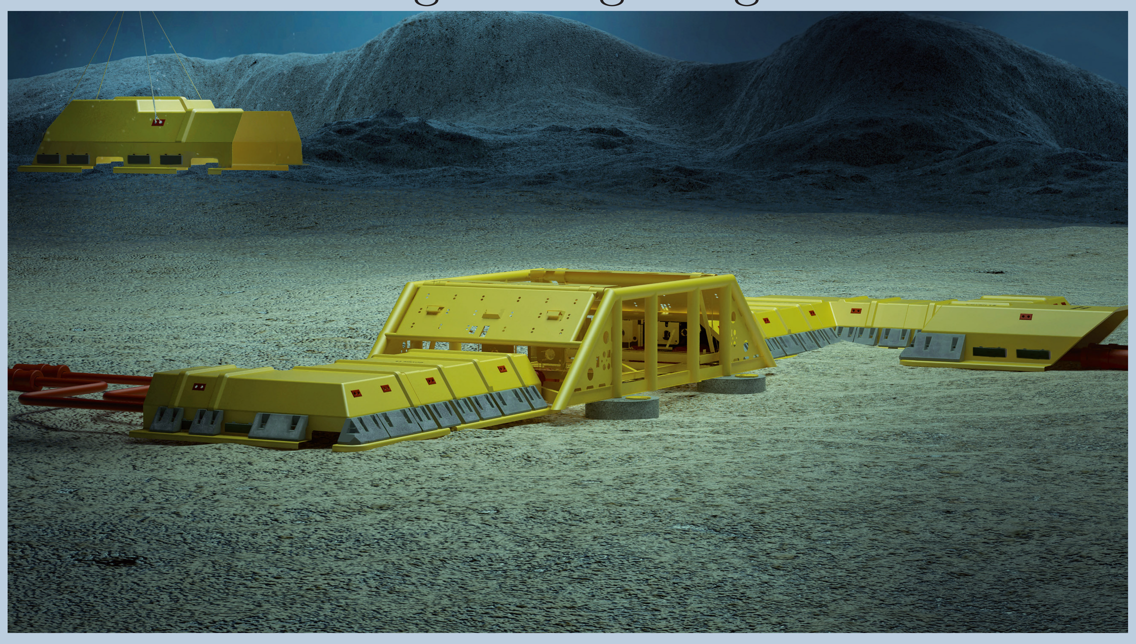

Figure 1: GRP covers[1]

Objectives

CFD is used to evaluate the hydrodynamic quantities such as drag and lift forces, pressure distribution and flow characteristics around simplified two-dimensional subsea structures. The shape of the structures analyzed are square, rectangle and the shape of GRP cover. The present numerical results are compared with available experimental data.

Modelling

Two-dimensional Reynolds-Averaged Navier-Stokes (RANS) equations are used together with the standard $k-\epsilon$ turbulence model. The set-up of the geometry is illustrated in figure 2. ANSYS CFX is adopted in this study.

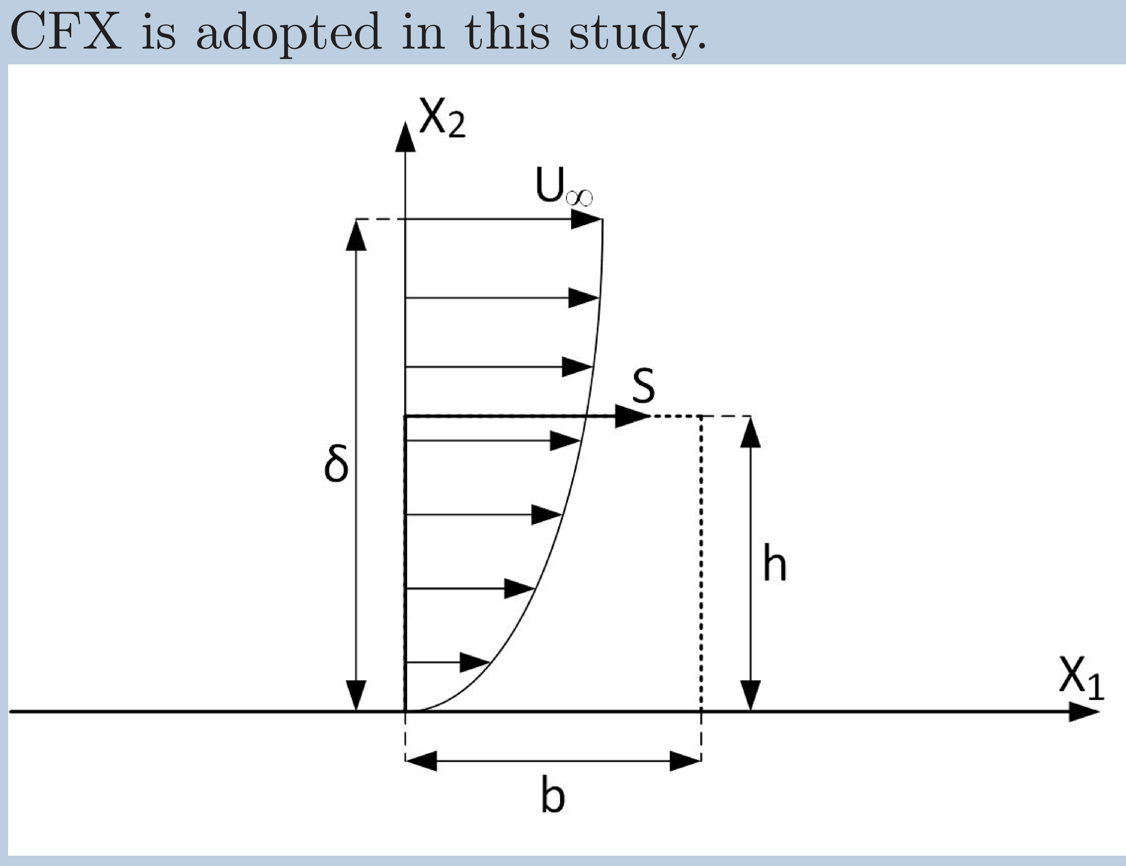

Figure 2: Set-up for two-dimensional square cross section

References

[1] Taken from *http://highcomp.no/wp-content/uploads/2013/03/CAD_field.jpg*

[2] Fujimoto, H., Isomura, M., Ajisaka, K. (1975), *Flow over Rectangular Cylinders Immersed in a Turbulent Boundary Layer*, Bulletin of the JSME, Vol. 18. No. 125

Results

All simulations have been performed at Reynolds number $Re_h = \frac{\rho U_\infty h}{\mu} > 3.4 \times 10^4$, where ρ is the density of the fluid, U_∞ is free stream velocity far from the seabed, h is the height of the structure, and μ is the kinematic viscosity. A high quality mesh is necessary when simulating such high Reynolds number flows and structured mesh is applied as shown in figure 3 and 4. Grid convergence studies have been performed and the mesh is found to be of good quality. The mean drag coefficient $C_{D,avg}$ and the mean lift coefficient $C_{L,avg}$ have been predicted and $C_{D,avg}$ are compared with published experimental data. When boundary layer thickness to height ratio $\delta/h \geq 1.7$, $C_{D,avg}$ is in good agreement with experimental results with a modest over prediction. The resulting value of $C_{D,avg}$ in the present study indicate a slightly larger over prediction when $\delta/h \leq 0.73$. These results are shown in figure 5. Hydrodynamic quantities for three values of boundary layer thickness to height δ/h and structure breadth to height b/h are illustrated. The hydrodynamic quantities for two simulations of simplified GRP covers are also included in figure 5. Streamlines are plotted for the simplified GRP covers and presented in figure 6 and 7 where $\delta/h = 1.7$.

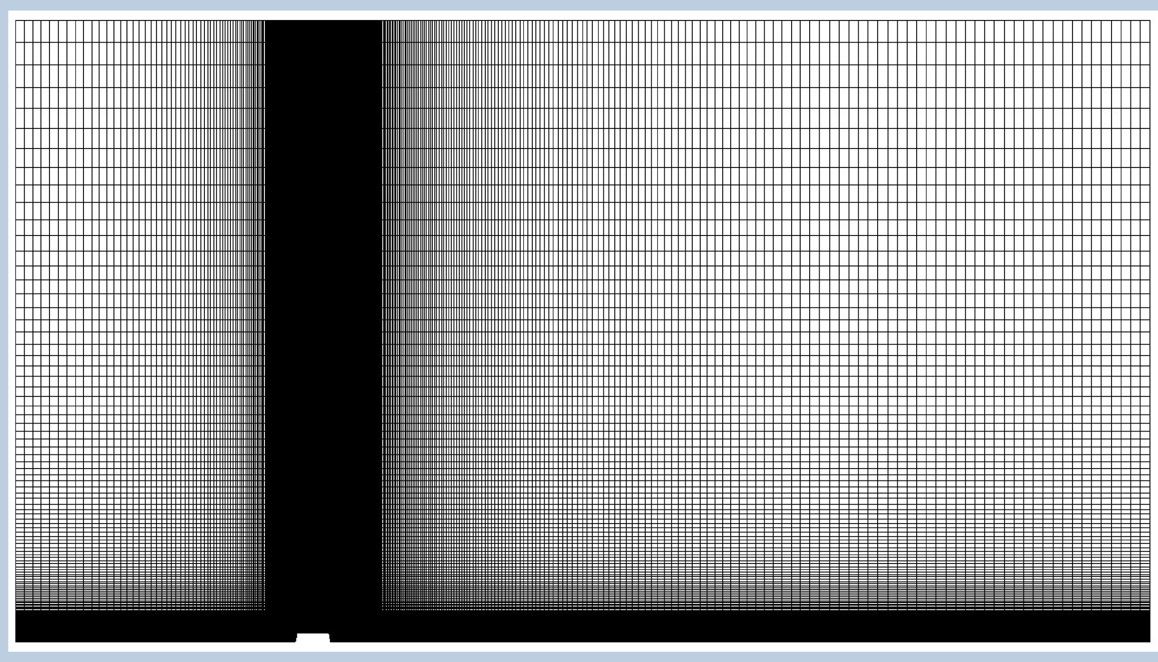

Figure 3: Global mesh

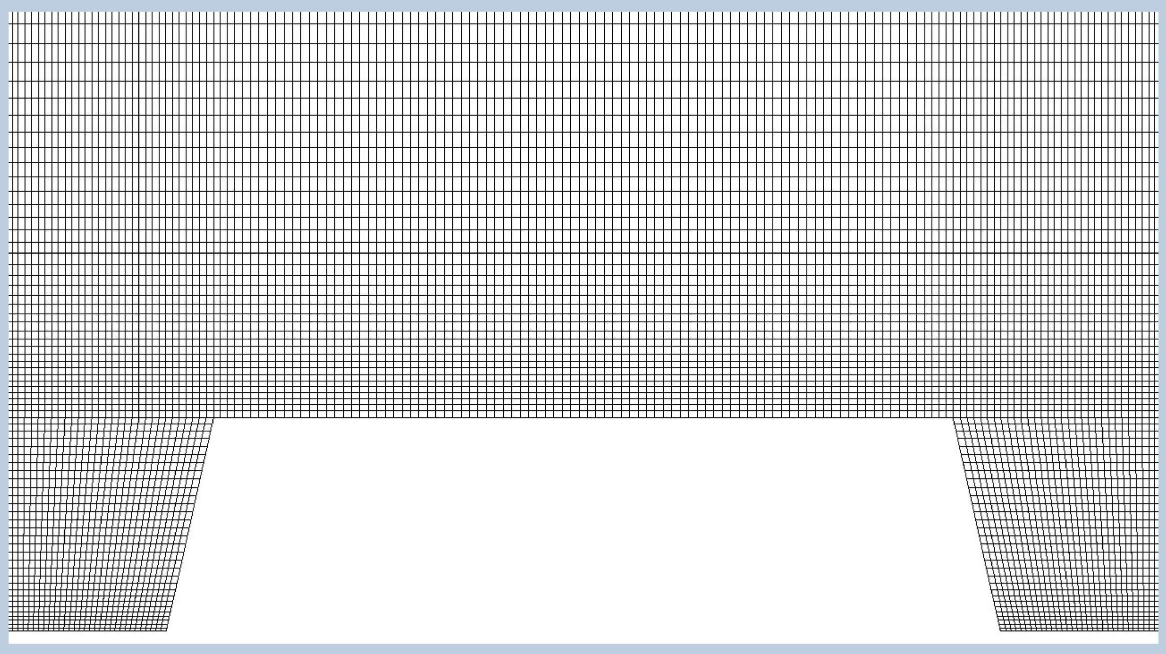

Figure 4: Local mesh

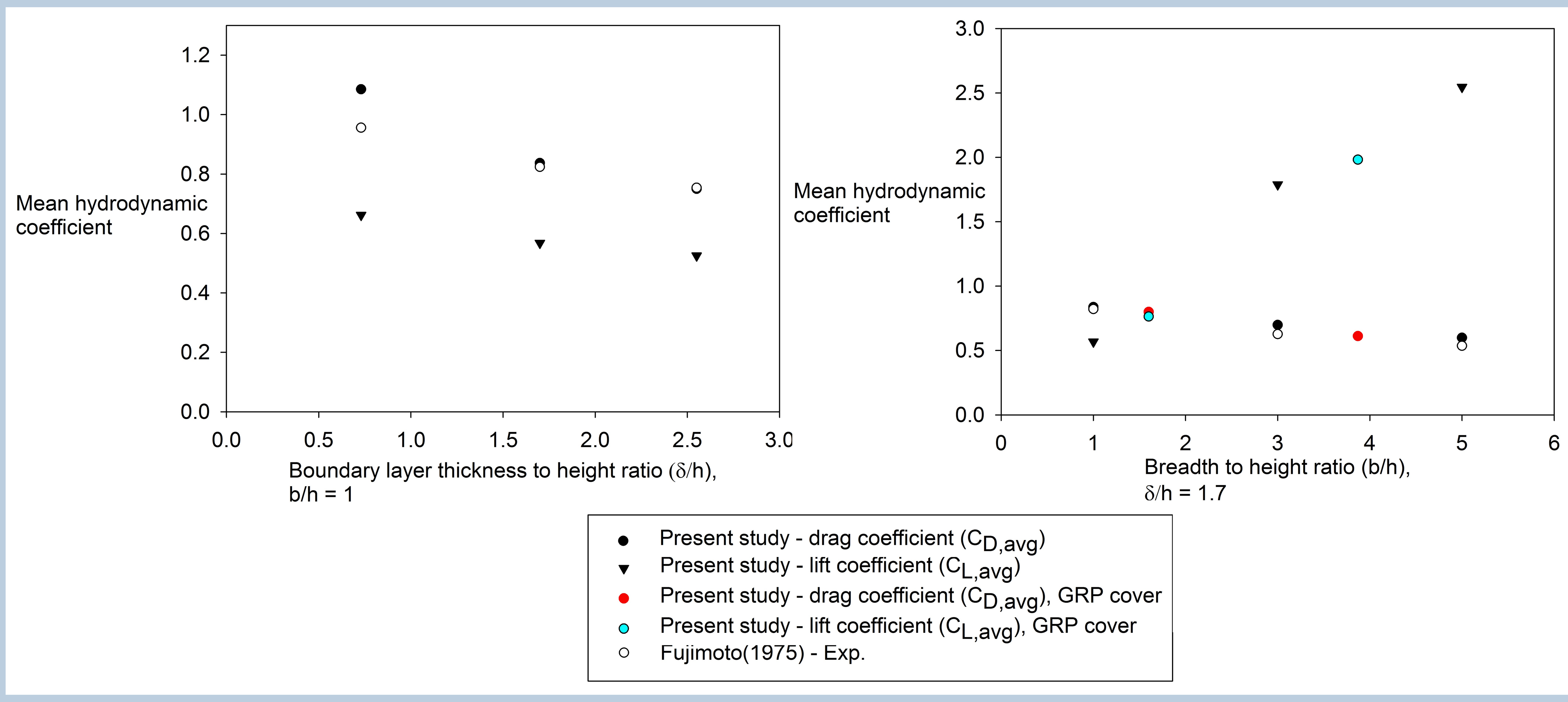

Figure 5: Mean drag ($C_{D,avg}$) and lift ($C_{L,avg}$) coefficients as function of δ/h and b/h for square and rectangular cross section as well as simplified GRP cover

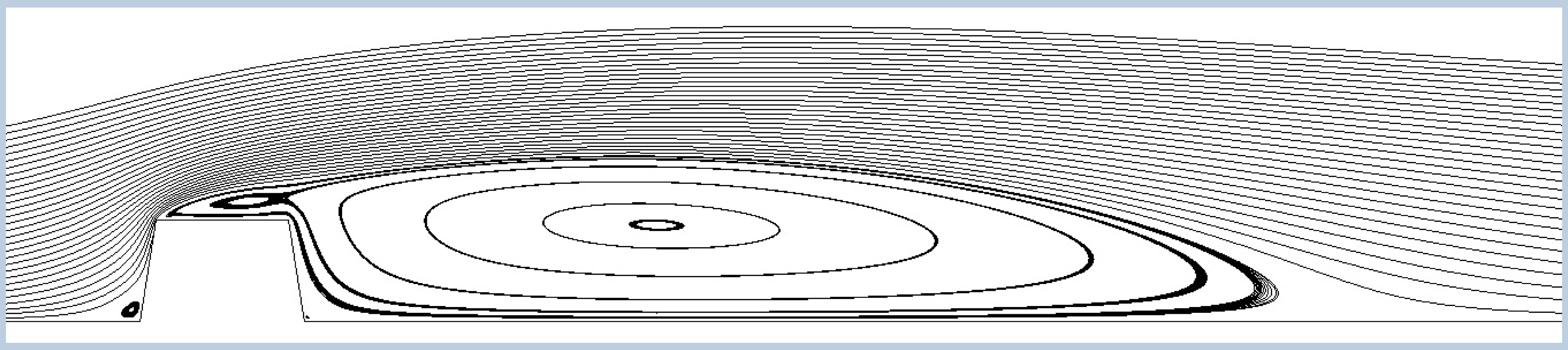

Figure 6: Streamlines for GRP cover with $b/h = 1.6$

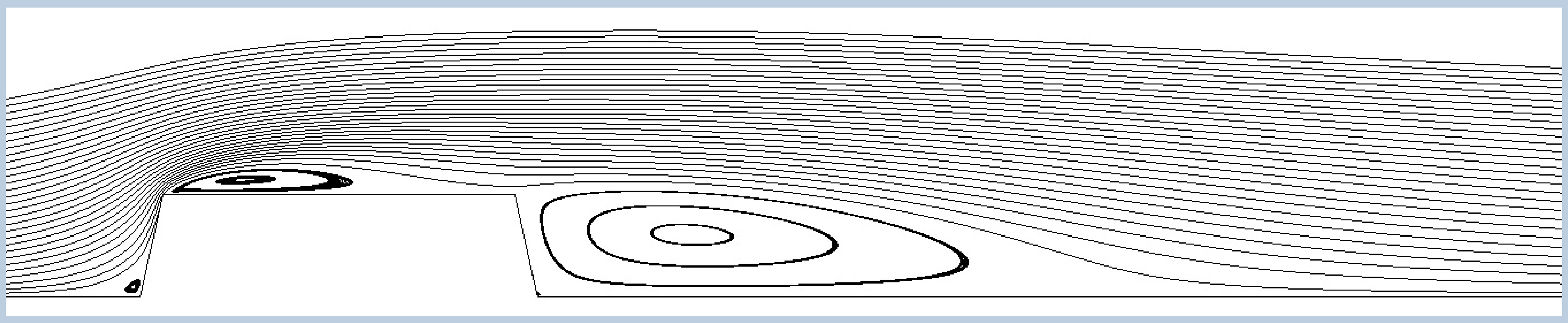

Figure 7: Streamlines for GRP cover with $b/h = 3.87$

Summary

It appears that the present CFD simulations are able to predict hydrodynamic quantities reasonably well for simple two-dimensional geometries on the seabed such as square and rectangular shaped structures. The method may be used to predict forces on GRP cover which is relevant for the stability of the covers on the seabed.