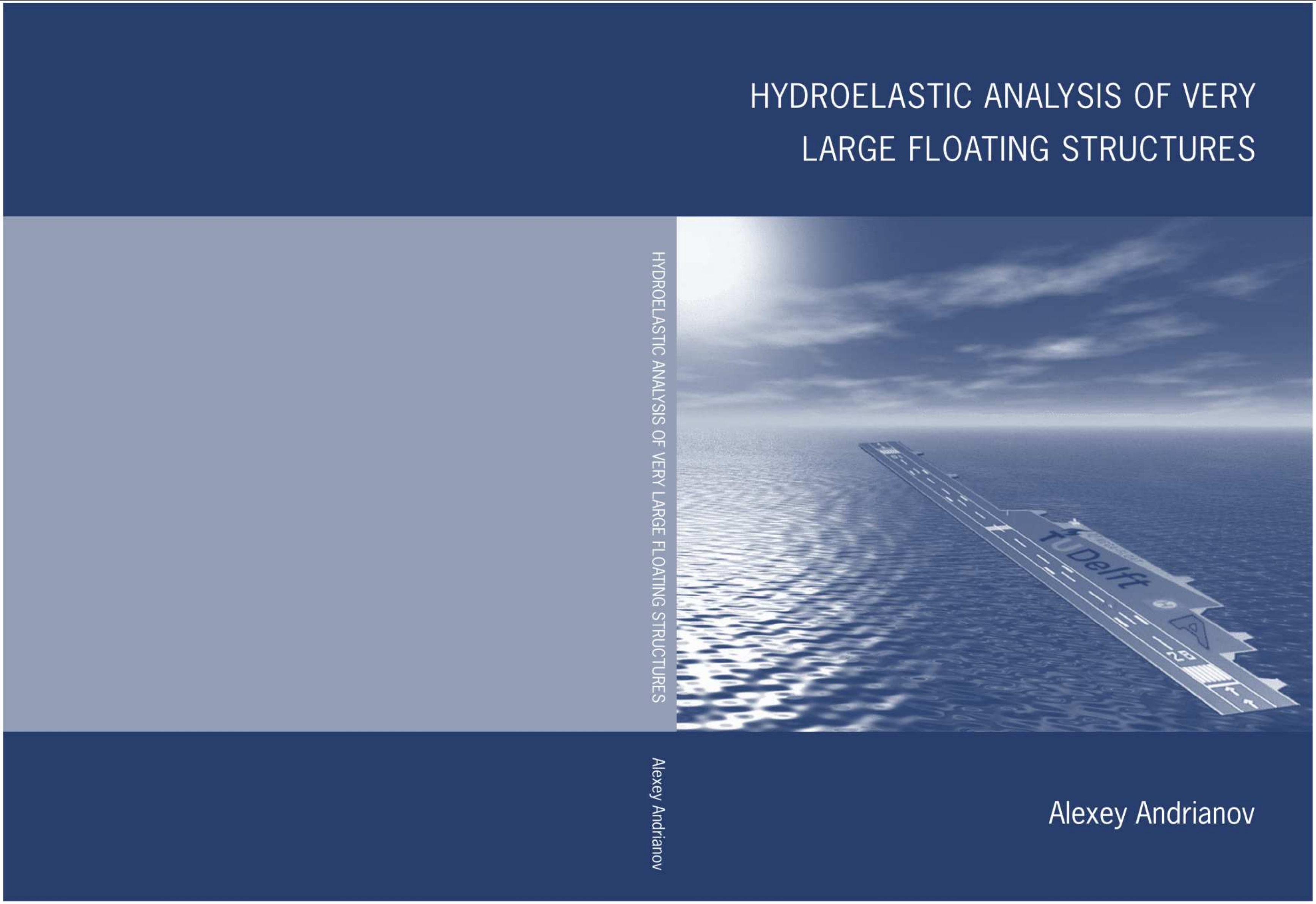
Hydroelastic Analysis of Very Large Floating Structures



HYDROELASTIC ANALYSIS of VERY LARGE FLOATING STRUCTURES

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Artificial islands or VLFS? And why VLFS?

Buy land. They've stopped making it.
Mark Twain, XIX century.

N.B. Production is resumed.
VLFS researchers, XXI century.

Many developed island countries and countries with long coastlines in need of land have for some time now been successfully reclaiming land from the sea to create new space and, correspondingly, to ease the pressure on their heavily-used land space. These works are, however, subject to constraints, such as the negative environmental impact on the coastlines of the country and neighboring countries and marine ecological system, as well as huge economic costs in reclaiming land from deep coastal waters. In response to the aforementioned needs and problems, researchers and engineers have proposed an interesting and attractive solution — the construction of very large floating structures.

Floating airport prototype

The Mega-Float, a floating airport prototype, Tokyo Bay, Japan.

VLFS

VLFS — Very Large Floating Structure. VLFSs can be constructed to create floating airports, bridges, breakwaters, piers and docks, storage facilities (for oil), wind or solar power plants, for military purposes, industrial space, emergency bases, entertainment facilities, recreation parks, space-vehicle launching, mobile offshore structures and even habitation (it could become reality sooner than one may expect).

VLFSs may be classified under two broad categories: the pontoon-type and the semi-submersible type. The former type is a simple flat box structure and features high stability, low manufacturing cost and easy maintenance and repair. The pontoon-type/mat-like VLFS is very flexible compared to other kinds of offshore structures, so that the elastic deformations are more important than their rigid body motions. Thus, hydroelastic analysis takes center stage in the analysis of the mat-like VLFSs.

VLFS: pro et contra

Advantages (over the traditional land reclamation):

⊕ they are easy and fast to construct (components may be made at shipyards and then be transported to and assembled at the site), thus, the sea space can be quickly exploited;

⊕ they can be easily relocated, expanded, or removed;

⊕ VLFSs are cost effective when the water depth is quite large;

⊕ the construction of VLFSs is not greatly affected by the depth of the water, sea bed profile, etc.;

⊕ the position of VLFSs with respect to the water surface is constant; hence VLFSs can be used for airports, piers, etc.;

⊕ the facilities and structures on VLFSs are protected from seismic shocks since the energy is dissipated by the sea;

⊕ environmentally friendly – they do not damage the marine eco-system, or silt-up deep harbors or disrupt the sea/ocean currents.

VLFS: pro et contra

Disadvantages:

⊖ mat-like VLFSs are only suitable for use in calm waters associated with naturally sheltered coastal formations (solution: use of breakwaters, anti-motion devices, anchor or mooring systems);

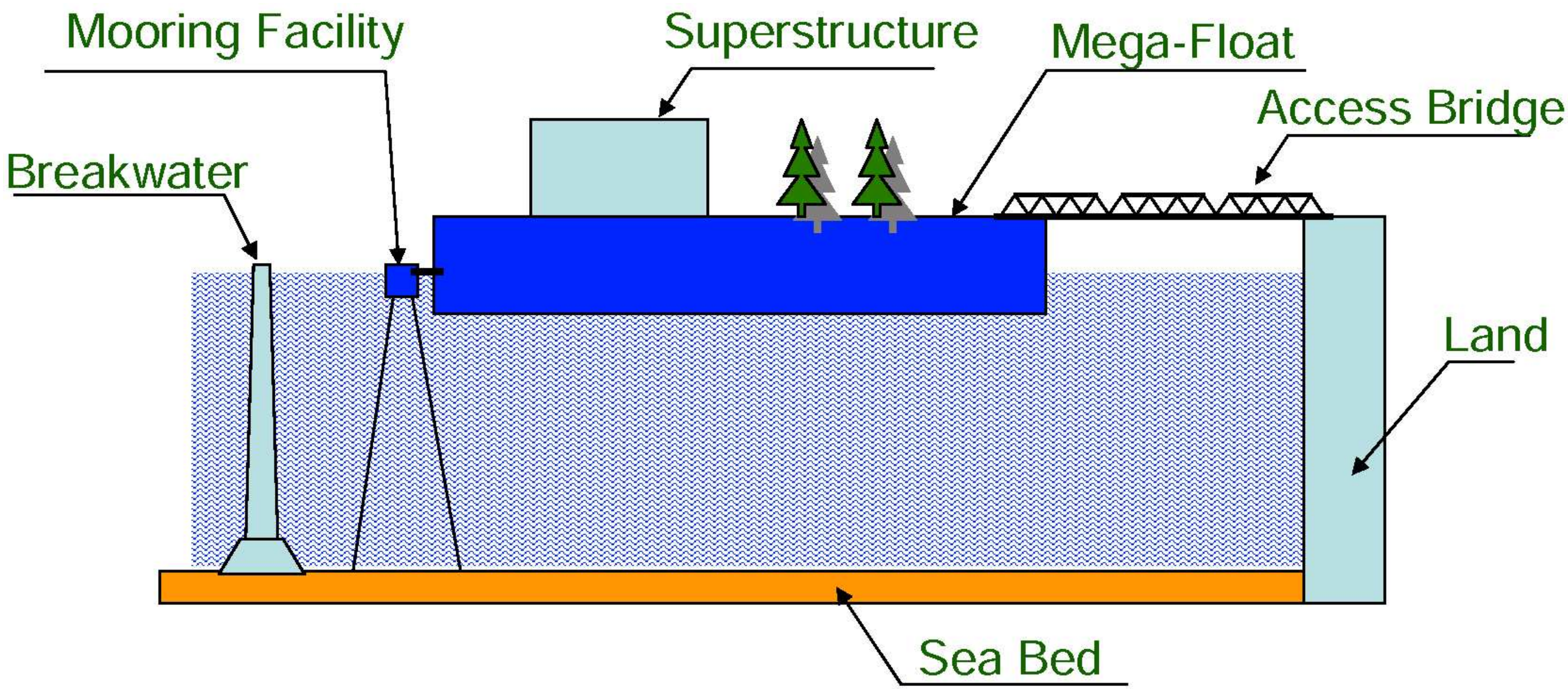
⊖ (might be) not sufficient stability for the airport control systems (solution: keeping these systems on a shore);

⊖ low security (bombing, terroristic attacks).

Floating bridge

Yumemai floating bridge, Osaka, Japan.

Components of the VLFS system



Components of a VLFS (Mega-Float) system.

Floating oil storage base

Kamigoto Oil Storage Base, Nagasaki Prefecture, Japan.

Mega-Float

Mega-Float, Tokyo Bay, Japan.

The **Mega-Float** was completed as a floating airport model in the Tokyo Bay (near Yokosuka) in 1998-99 by Technological Research Association of Mega-Float, a consortium of 17 companies.
Principal dimensions: length 1000m, breadth 60m (121m in max.), depth 3m, draft 1m, deck area 84,000m^2, weight of steel materials used 40,000t, deck strength 6t in distributed load.

Mega-Float: details

The Mega-Float is the world's largest floating object ever built. The Mega-Float consists of six units, which were welded into one huge structure measuring 1000m in length, 60m (partially 121m) in width and 3m in depth. The largest unit was 383m x 60m.

The Mega-Float was constructed for taking off and landing tests with use of rather 'light' aircraft, and to verify commercialization.

All reports of the tests show that the results were even better than expected. The platform has behaved very stable, with basically no movement caused by the waves or the planes landing or taking off. The unit was constructed of steel with walls or pillars inside a box structure, that was designed to have a life expectancy of 100 years.

Ice fields


Pancake Ice


Marginal Ice Zone

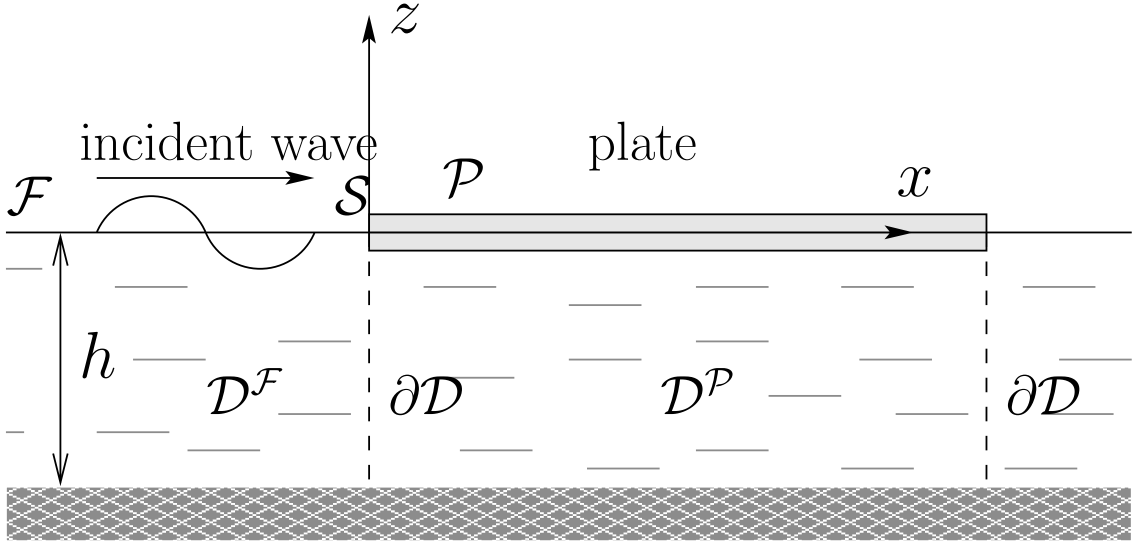
Contents of the thesis: chapters

1. Introduction.
2. General theory.
3. Semi-infinite plate & strip.
4. Circular plate.
5. Ring-shaped plate.
6. Quarter-infinite plate.
7. Plate of finite draft.
8. General conclusions and recommendations.

In chapter 2 the basic theory is given and the method proposed is described.

In chapters 3–7 the particular problems of the interaction of water waves with floating elastic plate are studied for different horizontal planforms of the plate.

General geometry of the problem, assumptions



General geometry of the problem.

Surface water waves incident on the floating flexible plate. Fluid is assumed to be ideal incompressible expanse of water, amplitudes are assumed to be small, there is no any space between the plate and water. The fluid domain is split up into two regions: open-water and plate regions. The general theory is divided into three cases: infinite, finite, which is of main interest for us, and shallow water depth.

What do we study?

- Plate motion.
- Reflection and transmission of incident waves.
- Initiated wave pattern and free-surface elevation.
- Comparison of the results for different plate planforms and parameters, water depth models.
- Influence of water depth and wave length on the plate behavior.

Some mathematics and physics

The velocity potential $\Phi(x, y, z, t)$ is a solution of the Laplace equation in the fluid,

$$\Delta\Phi = 0,$$

supplemented with the boundary conditions at the free surface (different for the plate and open-water regions) and at the bottom.

The Sommerfeld radiation condition has to be satisfied at far field.

The VLFS is modeled by a thin elastic plate; the thin plate theory of Kirchhoff is envoked. We are allowed to do this because of small thickness of the plate.

The Green's theorem is applied to the velocity potential in the plate and open-water regions.

Our method & other methods

Different forms for the Green's function are used. The plate deflection is represented as the series of exponential or Bessel functions multiplied by coefficients, as in the eigenfunction method.

We derive an integral equation for the potential and, further, an integro-differential equation for the plate deflection and free-surface elevation. Integro-differential equation method, developed and described in the thesis, allows us to solve different problems of the fluid-structure interaction.

Conclusions

- The analytical study for the deflection of a thin elastic plate, a model of VLFS, which is floating on the water surface has been presented in the thesis.
- The solutions are obtained for the different planforms of the plate and cases of the water depth theory. Thus, the integro-differential equation method developed is valid for different shapes of the floating plate.
- The hydroelastic motion of the floating plate has been studied for practically relevant cases.
- The method also has been extended to the case of finite thickness of the plate.
- The free surface elevation, initiated wave pattern, reflection and transmission of incident waves have been studied as well.
- The solution for the water of finite depth can be used for the problems with shallow or very ("infinitely") deep water.

Applications

VLFS-water interaction has been treated in this thesis. We studied the behavior of the very large floating structure in water waves.
The main application is the study of the hydroelastic motion of the VLFSs in water waves.
Also method can be applied to: the interaction between ice sheets or fields and water waves; small- and middle-sized floating structures behavior in water waves (breakwaters, pontoon bridges, etc.).

Application: VLFS, plate–water interaction

Application: ice–water interaction

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Happy End / Thank You

THANK YOU

Dank je wel nl

Spasibo rus

Dyakuyu ukr

Terima kasih ind

Merci boku fr

Arigatou jp

Grazie it

Danke schön de

More general information:

`Sections 1.1-1.2, 8.3-8.4 of the thesis`

Further information and details @:

`the thesis, http://www.andrianov.org`