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Some Aspects of Mega-Floating Airport Design and Production

Abstract

Mega-Floating Airports (MFA) are unique and complex offshore transport system components that emerged as a consequence of tremendous land price increase in the vicinity of very large coastal cities. An overview of MFAs design and production aspects is presented within this paper including design concept, model tests and full scale measurement, air transport analysis, infrastructure, main particulars and structure, wave breaker, hydroelastic analysis due to wave load and airplane moving mass, mooring analysis, production technology and environmental aspects. MFA dynamic response due to airplane load is emphasized as the most challenging problem. Theoretical outline as well as a realistic illustrative numerical example are presented.

Keywords: floating airport, air transport, offshore structure design, moving load, hydroelasticity

1. Introduction

Continuous growth of daily migration rates, [1], international airborne trade of goods and commodities, as well as different geographical obstacles and tremendous land price increase in the vicinity of very large coastal cities motivated harnessing of large and relatively unused sea and ocean spaces by means of different Very Large Floating Structures (VLFS) and particularly Mega-Floating Airports (MFA). Although an idea on mega-floaters dates back to the end of the 19th century, [2], public airport applications were not realized until 1995 when a Japanese government started a 200 million $ Mega-Float project, [3]. The main project result was a 1000 meters long thin-walled steel floating structure capable of performing usual land airport activities, Figure 1.

Figure 1. Mega-floating airport in Japan, [3]

Additional motivation for the development of MFA technology lies in several advantages as compared to land airports, particularly in the fact that floating structures are highly earthquake proofed structures with large storage capacity available below the main deck that can be easily rearranged to a different or more suitable layout. Along with that, due to floating property, their operational site is not influenced by the sea depth or significant environmental impact. However, some disadvantages like variable yearly airborne transport requirements, environmental loads (waves, sea current and wind load) in a relatively long design life, hydroelastic response, moving load due to airplane landing and take-off, restricted horizontal motions and mooring requirements, interconnections with land traffic infrastructure and demanding production technology indicate that MFA design and construction require a sophisticated approach based on advantageous analytical models capable of dealing with demanding physical problems in a mathematically transparent and thorough way, [4] and [5].

The existing and still actual problems motivated an extensive research performed by scientist worldwide that aimed towards formulation of mathematical models and methodologies suitable for accurate and fast analysis of MFAs dynamic response to environmental and moving load. Since length and breadth of a VLFS are significantly larger than the draft, such structure can be modelled as an elastic isotropic floating thin plate with free edges. Hydroelastic response of MFA to wave excitation is extensively presented in [6-10]. Additionally, classical problems related to the pontoon-type floating airport are the transient responses due to moving load as a result of airplane take-off/

landing, [11]. As reported in [12] and [13] there have been relatively few studies of VLFS transient problems in general. Hydroelastic response of MFA to at-sea towing is extensively presented in [14].

In the context of the above outlined state-of-the art, this paper represents an overview of the MFA design methodology with particular aspects of MFA model tests and full scale measurements, its infrastructure and structural properties, wave breaker, hydroelastic and mooring analysis as well as production technology and environmental impact that are addressed in more details in order to enable a further development and simpler implementation of the MFA technology for public purposes.

2. Design methodology

Clear definition of the design methodology including numerous stakeholders, design goals and their mutual interconnections is of crucial importance, particularly in the case of a complex problem such as MFA design and construction. The main goal during MFA design is to obtain a functional and environmental friendly structure that will enable conventional airport activities at sea during a long period while providing safety for both people and all necessary infrastructure in intact and damaged condition.

Prior to detailed design and construction development, preliminary dimensions have to be determined based on the design requirements, i.e. yearly airborne transport requirements in terms of number of operations, passengers and cargo quantity. Based on that data a number of required runways, boarding ports, storage rooms and passenger accommodation areas can be determined as well as necessary interconnections with land traffic infrastructure. When preliminary dimensions and layouts are determined conventional naval architecture analysis can be performed including MFA stability in intact and damaged condition, wave and mooring loading, quasi-static and dynamic structural analysis as well as fatigue evaluation. A detailed MFA design and construction flow chart is presented in Figure 2.

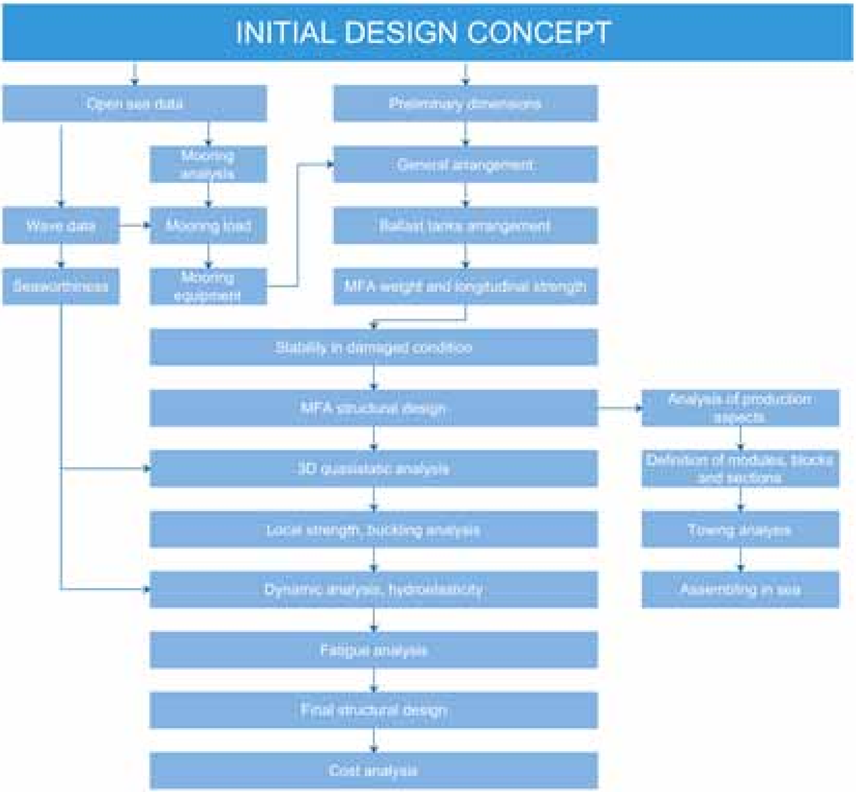

Figure 2. A detailed MFA design and construction flow chart

3. Model tests and full scale measurements

In order to obtain reference data for verification of the theoretical calculation models several dedicated model tests have been performed, [15]. In [16] fundamental laws of similitude regarding hydroelasticity were derived through analysis of free vibrations for vertical bending and torsion. It was found that floating elastic structures (assuming similarity based on the Froude number) can be characterized by six non dimensional parameters, were the elastic properties are described by respective vertical bending, torsional and shear rigidity. Additionally, valuable experimental guidelines were given by Lee and Webster [17] who analyzed model testing for the floating airports. An interesting approach using the small scale model and a very small water tank, utilizing optical measuring techniques, is outlined in [18]. Full scale measurements of fluid structure interactions are usually not readily available but because of the Japanese Mega Float project testing was done on a Mega Float Phase I model measuring

300 m x 60 m x 2 m and included measurements of motions, stress, noise, thermal deformation. Additionally, in order to further demonstrate feasibility of airport functions Mega Float Phase II model measuring 1000 m x 60 m (up to 121 m) x 3 m was constructed and tested using the commercial airplanes (Instrument Landing System tests and Take-off/Landing tests), [19].

4. Air transport analysis

Analysis of Air transport is the first step in MFA design resulting with a number of peak daily operations that will determine a required number of runways, passenger gateways and facilities for airplane repair, maintenance and overnight stay. Currently, the busiest world airport is the Atlanta airport with more than 47 million passengers yearly and is followed by Chicago, Dallas, Los Angeles, Denver, etc. airports, Figure 3. The busiest European airport is Charlles de Gaulle airport in Paris, while the most interesting and closest to the shoreline is the Narita airport being the predominant airport in Japan. According to Narita airport statistics, [4], Table 1, a daily average number of 629 operations are performed including 563 passenger and 66 cargo flights. A daily average number of passengers takes a value of 97520 terminal passengers, while a daily average of 5598 tons is manipulated within cargo operations. Except that, peak daily operations are declared to be about 670 operations in a day that, according to experience [?], can be successfully maintained using 2 runways, 100 gateways, 5 maintenance facilities and 40 overnight stay areas.

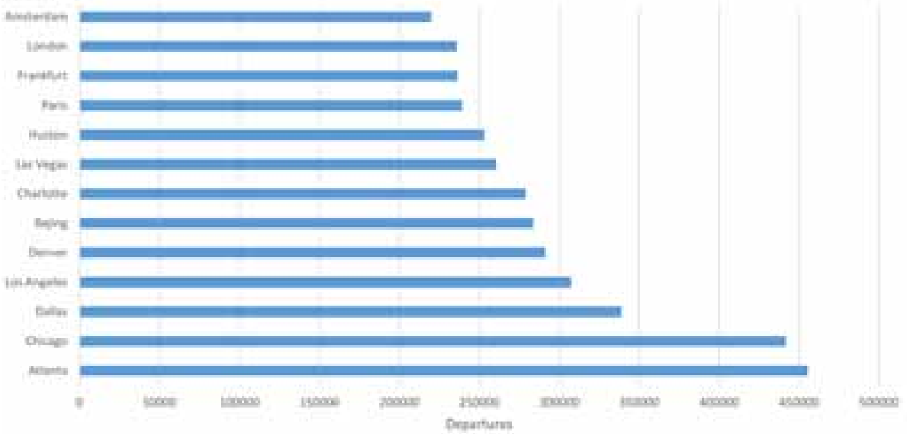

Figure 3 Number of departures in world busiest airports

Table 1 Narita airport statistics in 2014, average and peak daily operations

	Airplane operations (daily average)	Airplane operations (daily peak load)
PAX flight	563	602
Cargo flight	66	68
Total	629	670

5. Mega-float airport infrastructure

Based on the determined number of runways, gateways and maintenance and slipover areas it is possible to elaborate the MFA infrastructure. General airport infrastructure can be divided into three main parts (a) runways and other areas involving airplane operations (maintenance, loading, unloading, slipover, etc.), (b) navigation equipment for purposes of landing and take-off and (c) passenger, business and cargo areas including land traffic interconnections, [20].

5.1. Runways and areas involving airplane operations

According to recommendations of the Convention of International Civil Aviation Organization (ICAO), [20], the runway length, D, is to be determined according to

$$D = D_0\left(1+\frac{k_{nv}}{100}\right)\left(1+\frac{k_t}{100}\right)\left(1+\frac{k_u}{100}\right), \tag{1}$$

where D_0 is airplane landing length and k_{nv}, k_t and k_u are altitude, temperature and runway inclination coefficients. In case of airplane Boeing 747 $D_0 = 3300$ m and floating airport in the Pacific ocean near Japan coastline the unknown quantities are: $D_0 = 3300$, $k_{nv} = 0$, $k_u = 0$ and

$$k_t = t_{ref} - \left(t_{sa} - 0.0065h_{nv}\right) = 15, \tag{2}$$

where $t_{ref} = 30°\text{C}$ is Tokyo referent temperature, $t_{sa} = 15°\text{C}$ is standard temperature, and altitude $h_{nv} = 0$. Finally the runway length is equal to $D_0 = 3795$ m. The required runway width is determined according to [20] and is equal to 60 m, while the minimum distance between two parallel runway cannot be less than 400 m.

Other spaces involving airplane operations include slipover areas and maintenance workshops. If Boeing 747 is taken into account than the required areas can be determined according to its dimensions, i.e. length $L = 70.66$ m, breadth at wings $B = 64.44$ m and height $H = 19.40$ m. Therefore, maintenance workshop main dimensions are determined to be $L = 75$ m, $B = 70$ m and $H = 21$ m, while the same rectangular shape is applied for slipover areas at the open space.

5.2. Navigation equipment

Navigation equipment is an important part of the MFA infrastructure enabling safe landing and takeoff. It consists of visual and electronic component and is defined by the Convention of International Civil Aviation Organization (ICAO), [20]. Two basic navigation systems rely on visual landing and takeoff based on the system of lights. The Calvert system enables airplane positioning with respect to horizontal position of runway using lightning navigation system, while PAPI (Precision Approach Path Indicator) enables simple visual determination of the landing angle (about 3°). While Calver system can be relatively easy installed at the sea surface area in line with runways, PAPI system would require some improvement in order to take into account motions of sea surface and floating airport due to wave influence.

In case of low visibility due to weather conditions visual contact between pilot and light navigation system is not possible. Therefore, an electrical navigation system ILS (Instrumental Landing System) has to be used in order to ensure safe landing and takeoff conditions for airplanes. This kind of system composes of land based instruments that communicate with those installed within airplane by means of radio waves. Localizer system is responsible for horizontal positioning of airplane, while Glide Slope and Marker Beacon systems ensure the required landing angle.

5.3. Passenger and business areas

The main purpose of MFAs is to perform conventional land airport activities, i.e. to ensure efficient and safe passenger and cargo transport. Therefore, they have to be provided along with previously mentioned airplane operation and navigation infrastructure.

Passenger areas include passenger terminal including restaurants, bars, shops, language storages, ticket offices and boarding desks, hotel toll spaces, boarding areas and their communications with the rest of passenger terminal. Except that it has to be excellently connected to land traffic infrastructure, namely road, rail and sea transport infrastructure. Road and sea transport can be easily incorporated within global MFA layout, but it is suggested to place a train station at the shoreline as offshore train station would require complex rail connections involving fine motion compensators. Boarding areas and boarding gates are usually arranged in separated buildings with necessary stairways and ramps enabling fast and safe boarding and off boarding. As the peak airport loading in one hour is about 30 airplanes, the required boarding area length takes a value of about 2100 m (if Boeing 747 is taken into account). Along with that airport personnel spaces (e.g. rooms, restaurants, offices, etc.), language manipulation, police, fire department, medical care, flight control, helicopter, fuel and cargo areas have to be provided.

5.4. Main particulars

MFA main particulars can be determined based on previous considerations related to air transport analysis and required equipment. Thus, according to a similar project, the following particulars can be selected as the impute parameters for the first design loop:

Runway: L=4000 m B=60 m,
Passenger terminal: L=400 m B=250 m,
Toll and waiting area: L=900 m B=100 m,
Boarding area: L=2100 m B=150 m,
Garage: L=700 m B=250 m,
Police, fire department, medical care: L=400 m B=250 m,
Flight control: L=150 m B=150 m,
Maintenance area: L=400 m B=350 m,
Cargo and fuel area: L=800 m B=650 m.

General arrangement of the selected particulars is presented in Figure 4.

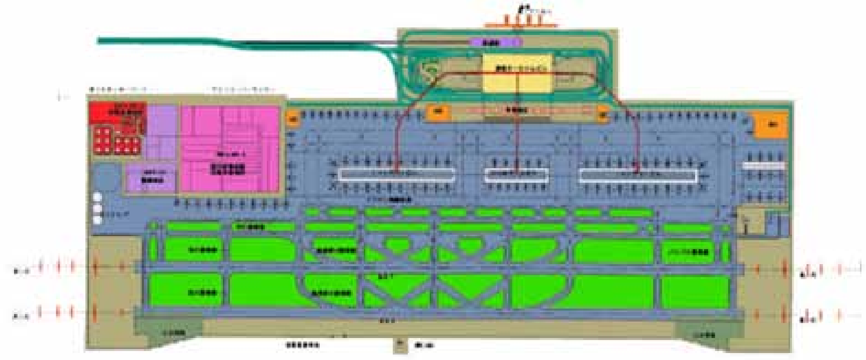

Figure 4. MFA general arrangement

6. Mega-float airport structure

Structural design of MFAs has to be conducted based on two load types, i.e. global hydroelastic loading that will determine its cross-section and local hydrostatic, wheel, equipment and infrastructure loading that will determine plate thickness, distance between profiles and their required cross sectional properties. As structural design based on local loading will influence global response and vice versa, it has to be conducted iteratively in a combination of topological and structural design variables with structural mass and production cost as objectives that have to be minimized.

Main structural components are stiffened plates placed between longitudinal and transversal girders, Figure 5. Their main particulars, i.e. plate thickness and stiffener properties, in airplane wheel load area, although conservatively, can be successfully determined using rule based approach, as in the case of car carrier structural design. Thus, according to the Croatian Register of Shipping (CRS), [21], thickness of the deck subjected to wheel load can be determined as

$$t = c\sqrt{P\left(1+a_v\right)k} + t_k\,, \tag{3}$$

where P is axis load, t_k is corrosion addition, $a_v = \dfrac{F}{m}$ is vertical acceleration determined according to the ratio between applied force, F, and mass, m, and coefficient c as function of the wheel patch area. Thickness of the rest of the plate area can be calculated similarly based on the local (hydrostatic, equipment, infrastructure, passengers) pressure applied.

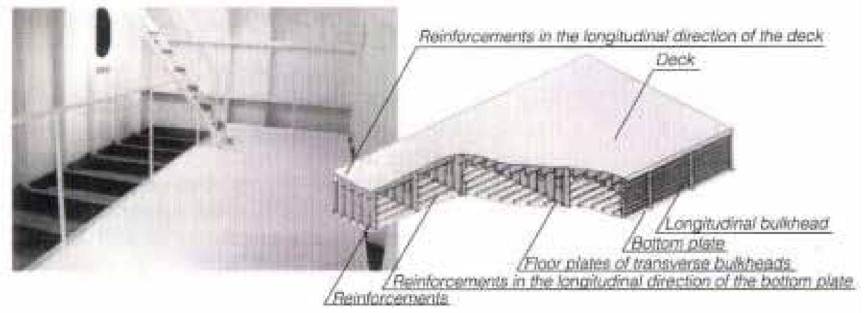

Figure 5 MFA structure

7. Wave breaker

Wave breaker represents an offshore structure build separately from the MFA, as its primary purpose is to protect the floating airport from wave loading coming from the open sea. Therefore, its structure and building process will be determined based on the wave spectrum in the considered area and on projected life that is usually more than 100 years. It is usually built by stone stacking or in some more complex cases by stocking of concrete objects of quadripod or tetrapod shape. Hudson equation, i.e.,

$$W = \frac{2600H^3}{K_D\left(S_a - 1\right)^3 \cot\alpha}\,, \tag{4}$$

where H is significant wave height, K_D is stability coefficient, S_a is density coefficient and α is inclination angle, is usually applied in order to determine the weight W required to sustain the incoming wave load.

8. Hydroelastic analysis

Because of its huge horizontal dimensions, MFA responses are dominated by the elastic modes and hydroelasticity becomes an issue with structure responding like a thin sheet floating on water.

The pontoon-like MFA in water is modelled as a free thin rectangular plate on elastic support. Differential equation of vibrations is presented in the form

$$D\Delta\Delta w + m\frac{\partial^2 w}{\partial t^2} + \rho g w = p_h - p_e , \tag{5}$$

where $w\ (x,\ y,\ t)$ is plate deflection, $D = \dfrac{Eh^3}{[12(1-v^2)]}$ is plate flexural rigidity (E – Young's modulus, v - Poisson's ratio, h – equivalent thickness of the pontoon thin-walled structure), $m\ (x,\ y)$ is mass per unit area, $\Delta(.) = \partial^2(.)/\partial x^2 + \partial^2(.)/\partial y^2$ is two dimensional Laplace differential operator, $\rho g w$ is hydrostatic pressure, $p_h\ (x,\ y,\ t)$ is hydrodynamic pressure, and $p_e\left(x(t), y(t), t\right)$ is local time-dependent moving pressure due to landing and take-off of an airplane. Negative sign of p_e in (5) is related to landing load acting vertically downward. Due to local moving load and hydrodynamic forces governing differential equation of motion (5) cannot be solved analytically and the modal superposition method is usually utilized. The forced response of a plate is assumed as a series of products of the free plate natural modes and corresponding time functions

$$w(x,y,t) = \sum_{j=1}^{\infty} W_j(x,y)T_j(t) . \tag{6}$$

In [11] it is recognized that solution of the equations of motion for a thin floating plate, within the modal superposition method, can be categorized into two classes of methods: i. the eigenfunction expansion method, where the modes used are usually numerically calculated by the finite element technique for free plate (*physical modes*) and ii. the methods where the response is expanded in modes other than the eigenfunctions of the thin plate (*mathematical modes*). In the latter case those modes are often products of free-free beam modes, 2D polynomial functions or even sine functions.

The plate natural mode can be assumed in the form of a series

$$W(x,y) = \sum_{j=1}^{\infty} C_j Z_j(x,y) , \tag{7}$$

where C_j are unknown constants and $Z_j\ (x,\ y)$ are appropriate deflection functions, which individually have to satisfy at least the geometric boundary conditions. Functions $Z_j\ (x,\ y)$ are usually called the mathematical natural modes, while $W\ (x,\ y)$ are physical natural modes.

The mathematical natural modes for a free plate in (7) are usually assumed in the form of product of free beam natural modes,

$$Z_i(x,y)=\left[X_m(x)Y_n(y)\right]_i,\quad Z_j(x,y)=\left[X_k(x)Y_l(y)\right]_j, \tag{8}$$

where m, $n = 1, 2... M$ and k, $l = 1, 2... N$.

Using the Green function method, implicitly satisfying the boundary conditions at the free surface and the radiation condition, linear water-wave problem is solved using the Boundary Integral Equation method, which in the discretized form reads

$$\frac{1}{2}\sigma(P_i)+\sum_{j=1}^{N}\sigma(P_j)\cdot\frac{1}{4\pi}\iint_{s_j}\frac{\partial}{\partial n}G(P_i,Q)\,\mathrm{d}S(Q)=f_p(P_i),\quad i=1,2...,N, \tag{9}$$

where σ is the unknown source strength, $G\ (P,\ Q)$ is the free surface Green function, [22] and [23], $f_p(P_i)=\vec{Z}_j\cdot\vec{n}$ is the generalized radiation mode projected onto corresponding panel unit normal, N is the total number of panels discretizing the wetted surface of the body and S_j is the surface of the corresponding panel. After the unknown source strengths have been solved velocity potential for the radiation problem is calculated using

$$\phi(P)=\sum_{j=1}^{N}\sigma_j\cdot\frac{1}{4\pi}\iint_{S_j}G(P,Q)\,\mathrm{d}S(Q). \tag{10}$$

After the radiation potentials have been calculated modal added mass and damping read

$$A_{ij}(\omega)=\mathrm{Re}\left\{\rho\int_{S_B}\phi_j\,\vec{Z}_i\cdot\vec{n}\,\mathrm{d}S\right\},\quad B_{ij}(\omega)=\mathrm{Im}\left\{\omega\rho\int_{S_B}\phi_j\,\vec{Z}_i\cdot\vec{n}\,\mathrm{d}S\right\}, \tag{11}$$

where ϕ_j is the i-th mode radiation potential and S_B is the wetted surface of the pontoon.

System of the pontoon modal equations has to be extended with the hydrodynamic inertia and damping force, as well as structural damping force

$$\sum_{j=1}^{\infty}\left\{A_{ij}(\infty)\ddot{T}_j+\int_0^t K_{ij}(t-\tau)\dot{T}_j(\tau)\,\mathrm{d}\tau\right\}+M_i\ddot{T}_i+D_i\dot{T}_i+(S_i+R_i)T_i=F_i(t),\quad i=1,2...\,, \tag{12}$$

where D_i is structural damping coefficient, $A_{ij}(\infty)$ is infinite frequency added mass, and

$$K_{ij}(t)=\frac{2}{\pi}\int_0^{\infty}B_{ij}(\omega)\cos\omega t\,\mathrm{d}\omega \tag{13}$$

is the frequency dependent part of the wave radiation force. Matrices $A_{ij}(\infty)$ and $K_{ij}(t)$ are full matrices, and consequently the modal equations are coupled. Integral in (12) is the impulse response (memory) function, which can be calculated from the linear frequency dependent damping coefficient (11), according to Cummins [24].

In terms of moving load excitation of MFA it is assumed that an airplane moves along the runway during landing and take-off uniformly accelerated, with a given constant acceleration a_0. The airplane velocity and position read

$$v(t) = v_0 + a_0 t, \quad x_p(t) = x_0 + v_0 t + \frac{1}{2} a_0 t^2 , \tag{14}$$

where v_0 and x_0 are the airplane initial velocity and position, respectively.

The airplane lift force is calculated by the formula, [13]

$$F_L(t) = \frac{1}{2}\rho_a A_w v^2(t) C_L(t), \quad C_L(t) = a_L \,\mathrm{e}^{b_L t} , \tag{15}$$

where ρ_a is air density, A_w is effective wing area, $C_L(t)$ is coefficient of the lift force with constant but different values of parameters a_L and b_L for landing and take-off, [13].

The total force acting on a plane is difference between its weight, Q, and lift force

$$F(t) = Q - F_L(t) . \tag{16}$$

In the modal superposition method the modal excitation load is specified by

$$F_i(t) = -\int_{-b}^{b} \int_{-a}^{a} p_e\left(x(t), y(t), t\right) W_i \,\mathrm{d}x\,\mathrm{d}y . \tag{17}$$

Since integration of local pressure per pontoon area results in lumped total force $F(t)$, its work, which represents modal force, reads

$$F_i(t) = -F(t)\, Z_i\left(x(t), y(t)\right), \tag{18}$$

where the modal index i corresponds to one combination of the indices m and n. As an example of hydroelastic analysis landing and take-off of a Boeing 747-400 airplane on/off rectangular floating airport is considered (airport and airplane data is taken from [13]). Structural response has been calculated at 9 different points along the length of floating airport (P1-P9). Initial conditions for the take-off analysis are zero velocity and initial static deflection due to airplane mass loading at point P3, determined by solving (12), in which the inertial and damping terms are neglected. In the case of landing analysis, initial conditions are zero static deflection and velocity. The airplane lands on the floating airport at point P3. Forced vibration analysis is performed by taking 48 modes into account. Governing system of coupled ordinary differential equations, (12), is solved using the explicit 4th order Runge-Kutta method and Dormand and Prince coefficients. In order to calculate hydrodynamic coefficients reliably, wetted surface of the pontoon has been discretized into 20300 panels. Displacement time histories measured along the length of floating airport are given in Figures 6. and 7. Resulting perspective view of floating airport vertical deflections at different time instants is given in Figures 8. and 9. As can be noticed, structural deformation is of the order of 1 cm. Effect of hydroelasticity can be clearly identified. It should be noted that in both landing and take-off analysis it was found that the influence of structural damping was very small in terms of the response amplitudes.

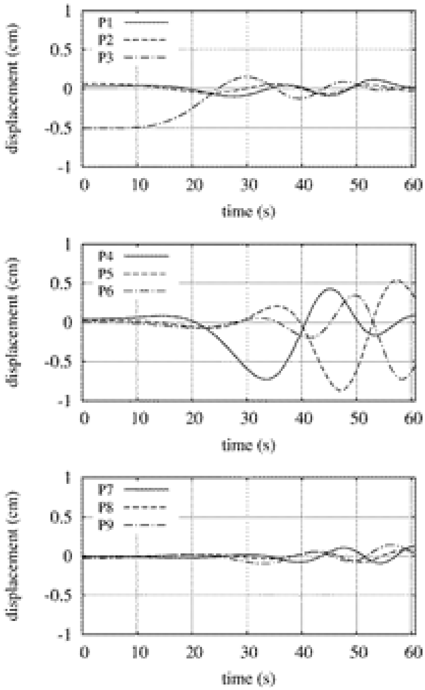

Figure 6. Take-off time history

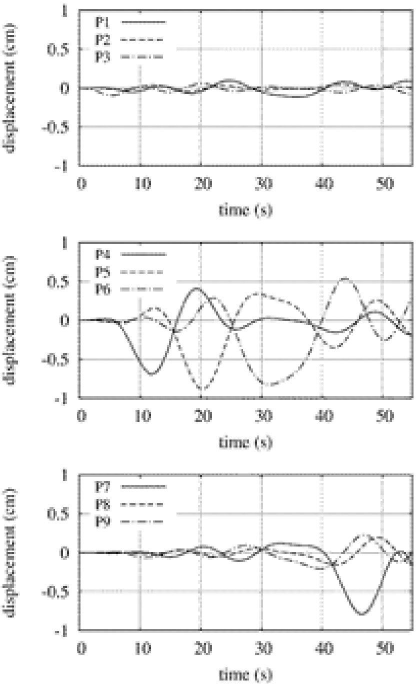

Figure 7. Landing time-history

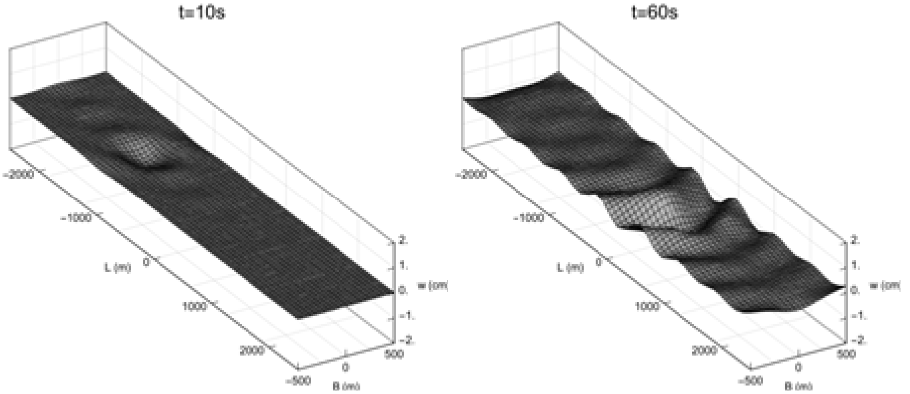

Figure 8. Perspective view of VLFS vertical deformations due to take-off

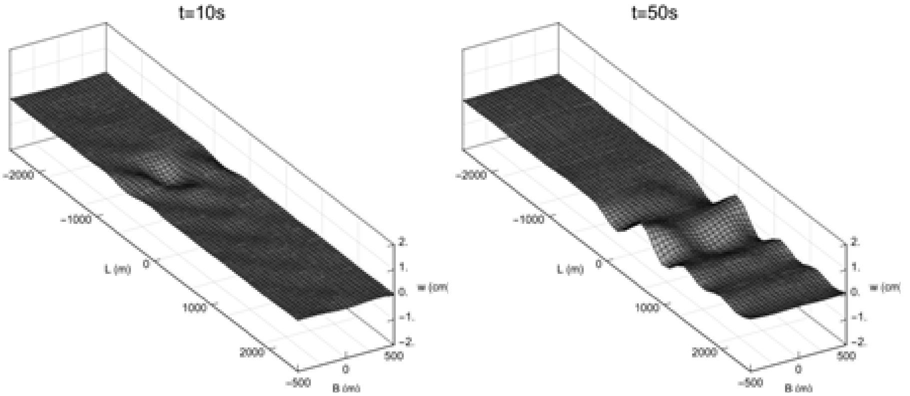

Figure 9. Perspective view of VLFS vertical deformations due to landing

9. Mooring analysis

In terms of requirements for the mooring system design it is recognized that MFA is moored in the shallow water, therefore encountering more extreme sea states than deepwater facilities. Because of the wave loading nonlinearity mooring analysis should be performed in the time domain. Additionally, due to the aviation requirements, mooring system has to ensure minimal motions in the horizontal plane resulting in a number of jacket fender-type mooring dolphins equilibrating primarily large first order wave forces (as opposed to ships and floating offshore platforms were the second order wave forces are primarily equilibrated), [25], [26] and [27]. One should note that jack mooring dolphins are usually modeled as rigid bodies (rigidity of the rubber fender is much lower than that of the dolphin). Different mooring systems can be seen in Figure 10, [28].

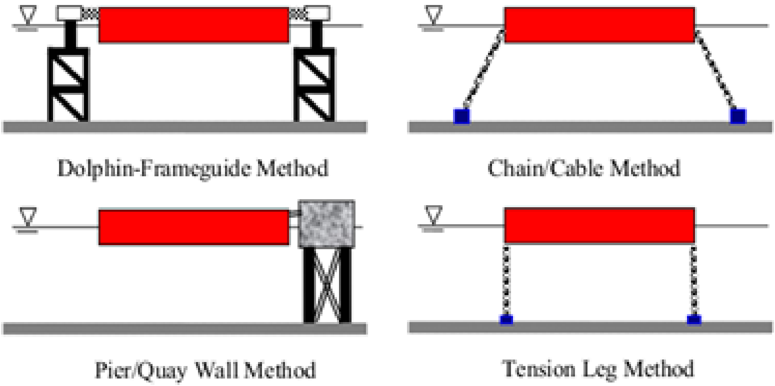

Figure 10. Various types of floating airport mooring systems, [28]

10. Production technology

Once designed, MFA can be produced in shipyard as its structure is similar to ship structure. Usual production process can be easily applied starting from prefabrication stage up to fabrication of MFA modules that, due to MFA scale, have to be joined in sea. Since most of the structural components consist of stiffened panels they can be produced using panel lines and assembled afterward to modules in shipyard section assembly workshops using common production practice.

Since MFA design life is determined to at least 100 years special attention has to be provided to surface protection that will enable such a long operative life with minor repairs in harsh marine environment. One possible solution is to apply titanium at steel surface as protective material. Its important property is 0.003 mm yearly attenuation in marine environment. Thus, a 3 mm titanium layer would sustain 100 year design life with regular underwater monitoring and maintenance. From technology perspective, a special explosive welding operation has to be applied in order to properly connect two plates made of different materials at significant surface. This procedure is similar to one applied in bimetal tape production applied in cruise and LNG ship production and consists of a serial explosions applied at material surface that force steel and titanium molecules band together in a tight connection, Figure 3.

Once built, MFA modules have to launched to the sea depending on building sight. As it is well known three basic building sights can be pointed out: dry dock, land level ground and slipway. However, from economic point of view the best and cheapest building sight is land level ground out of the main material fluxes containing shipyard's core business, i.e. ship production. Therefore, the best way to perform module launch is to apply pontoons that are towed to MFA assembling site and then inclined to launch the particular module to the sea. Alternatively, modules can be successfully launched using tipping table, [ ]. Module assembling is quite complex task that depends on module production quality and weather conditions. In addition a problem of welding bimetal other shell elements makes it even more complex. Module assembling procedure, Figure 5, can be performed using tugs and well known underwater U shaped tunnels used for welding process. However, according to the authors' best knowledge a problem of steel-titanium bimetal plates has not been solved up to date. One possible solution is to perform usual welding practice for steel component, while filling up the empty titanium layer using steel-manganese-silica electrode.

11. Environmental aspects

Installation of MFA to the environment raises important question of its impact to the surrounding sea ecosystem. Two most important environmental aspects are related to MFA and wave breaker shades and their influence to natural water flows, waves and salinity grades.

MFA shade, due to its large area will block insolation to a significant volume of underwater space disabling in such a way running of usual primary production processes resulting in organic and inorganic substances. On the other side, MFA and wave breaker presence will change the flow pattern in a selected MFA sight, but such analysis requires sound and thorough approach based on modern CFD methodologies and topographical characteristics. Nevertheless, the presence of MFA and wave breaker must not have significant influence on the incoming and outgoing sea current in order to ensure satisfactory level of natural bay ventilation.

12. Conclusion

An overview of Mega-Floating Airports, unique and complex offshore transport system components, design and production aspects were presented throughout this paper including design concept, model tests and full scale measurement, air transport analysis, infrastructure, main particulars and structure, wave breaker, hydroelastic analysis due to wave load and airplane moving mass, mooring analysis, production technology and environmental aspects. Hydroelastic analysis due to airplane moving mass was pointed out as important and complex problem contributing significantly to MFAs structural integrity. Theoretical outline as well as a realistic illustrative numerical example were presented.

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Neki aspekti projektiranja i gradnje velikih plutajućih aerodroma

Sažetak

Iznimno veliko povećanje cijene zemlje u blizini velikih obalnih gradova rezultiralo je pojavom velikih plutajućih aerodroma koji predstavljaju jedinstvenu i složenu pučinsku komponentu transportnog sustava. Pregled projektnih i proizvodnih aspekata velikih plutajućih aerodroma u ovom radu uključuje projektni koncept, modelska ispitivanja i mjerenja u naravi, valobran, hidroelastičnu analizu uslijed valnog opterećenja te uzlijetanja i slijetanja zrakoplova, analizu sidrenja, tehnologiju gradnje i utjecaj na okoliš. Dinamički odziv strukture na opterećenje uslijed gibanja zrakoplova je istaknut kao iznimno zahtjevan problem. Teorijski pregled ilustriran je jednim numeričkim primjerom iz prakse.

Ključne riječi: plutajući aerodrom, zračni transport, projektiranje pučinskog objekta, pomično opterećenje, hidroelastičnost