Water City As Solution To Escalating Sea Level Rise In Lower-Lying Land Areas

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***Abstract*— Strenuous efforts have been continuing to reverse the trend in global environmental deterioration and create a sustainable society. Despite the wide-ranging movement to reduce greenhouse gas emissions, substantial progress is yet to be seen. In this paper, a new concept for establishing urban community bases to be built on floating foundations in an artificial reservoir, enabling realization of a sustainable city environment toward a prosperous future is presented. This paper introduces our idea as applied to Koto Ward in the Metropolis of Tokyo. Although a portion of this plan has been offered in the latest papers of MTS/IEEE/Oceans'11 and Oceans'12, we have since then expanded the area covered by some 2 km from north to south and between 0.5 and 1 km east to west, with a total land area of approximately 1.25 km^2. The area encompasses a variety of city functions such as office buildings, commercial areas and recreational sites. We also present herein the construction scheme and engineering studies for high-rise structure stability on floating foundations, in addition to flood prevention measure in the excavated water area and/or artificial reservoir.**

Keywords— sustainable; floating structure; lower-lying land; Mega-Float; waterfront

I. INTRODUCTION

In order to establish a sustainable society, many countries have initiated strategies and regulations to reduce greenhouse gas emission in recent years. However, it seems almost impossible to halt the rising sea level brought about by global warming and the consequent speed of land disappearing under the sea. In fact, it appears that this phenomenon will accelerate further in the future. Moreover, there are many who believe storm surges, abnormally high waves and localized heavy rain caused by powerful typhoons that continue to intensify in strength under the influence of global warming, will strike several cities throughout the world and bring about devastating flood damages. The situation is made even worse by the serious danger facing many cities where large urban areas are below the high water level (zero-meter zone), and that are mostly located near a river and/or the sea. Even if the global environment improves in the future as a result of regulations against greenhouse gas and other effects, it does not necessarily follow that there will be a reduction in the frequency of worldwide disasters. Thus, the work must be begun immediately to construct social infrastructures that are capable of withstanding any global climate change and that will avert any disasters. It can be assumed that if nothing is done, the residents of cities with zero-meter zones will suffer substantial damage and consequent economic loss as a result of localized heavy rain and the subsequent overflow of rivers. Therefore, we urge that effective solutions that will minimize the damage from natural disasters be devised and implemented as soon as possible.

As flood prevention measures, large-scale structures such as seawalls have been constructed in many countries including the Netherlands. But under the present circumstances where the sea level continues to rise and global climate changes have brought about very real fear of large-scale flooding in many local areas, safety in most urban areas around the world cannot be guaranteed without massive public spending. To make matters worse, if these large-scale flood prevention measures were destroyed, the resulting catastrophe will claim many lives in an instant. Actually, in March 11, 2011, powerful breakwaters constructed near the shores of northeast Japan which had been believed to be most reliable in the world had been completely destroyed by tsunami and resulted in tremendous numbers of victims and the shocking truth highlighted by this disaster was that it is impossible to counter such extreme power of nature by using huge civil engineering structure.

This study proposes a simple and economical method of addressing these issues. The idea behind this method is

Fig. 1 Artist's Rendition of Water City

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introduced in Reference [1] while the economic investigation had been conducted in detail in Reference [2]. The concept is of a waterfront that is developed by excavating the soil in a low ground area down to a few meters below the surface and then flooding the area to construct an artificial reservoir. The foundations for an urban community float in the artificial reservoir, and buildings and other facilities are constructed on these floating foundations. Thus safe comfortable social infrastructures can be constructed in urban zero-meter zones (See Fig. 1). They will withstand flood disasters and will never submerge even if the sea level rises. An added benefit is that the floating structures will have an excellent seismic resistance. In order to materialize this proposal, a study has been conducted with the financial assistance of the Industry-Academic-Public Cooperation Center of the Tokyo Metropolitan University. A plan was evolved for a floating city and its economic efficiency and technical validity were evaluated on the assumption that an actual site in Koto Ward of Tokyo was to be redeveloped.

A number of proposals to build floating structures began to emerge in the U.S. from the late 1950s as a means to address land and population issues. In the 1970s, various solutions to resource and energy problems were suggested to take advantage of the ocean surface and promote power generation, water distillation and resource storage. During the 1990s, with the aim of realizing the construction of an offshore airport, the Mega-Float Technological Research Association was established around a core of Japan's shipbuilding industry. In the final stage of this research project, a 1,000 m long floating airport model was actually built and floated on the sea, for the purposes of verifying the construction procedure of such a super-large floating structure, testing conditions for aircraft takeoff and landing, and simulating the impact on the environment. The experiments have already produced excellent results. The Mega-Float Project has been subsidized at great expense by the Japanese government and private enterprises during a long period of time, and the project staff is considering how to make the best use of the valuable data and findings of the experiments as well as developing construction techniques for the project.

II. PROCEDURE BEHIND WATER CITY CONSTRUCTION

Procedures have been already demonstrated precisely in previous papers (Oceans'11 [3] and Oceans'12 [4]). Therefore only our idea is presented briefly here. An example of a low-lying waterfront zone at sea level near an ocean and/or river is illustrated below. The plan is to change the potential danger in this site and to produce an area that is safeguarded against natural disaster. An outline of the process follows:

Step 1 An area equivalent to approximately half of the total area of the site is excavated up to a depth of several meters. The topsoil removed from the site is relocated in order to raise the urban site above sea level (See Fig. 2① and Fig. 2②).

Step 2 Concrete levees prevent erosion or destruction of the bank. The area inside the levees is then flooded until the water level inside the levees reached that of surrounding sea and/or river, to construct a man-made inlet and/or basin.

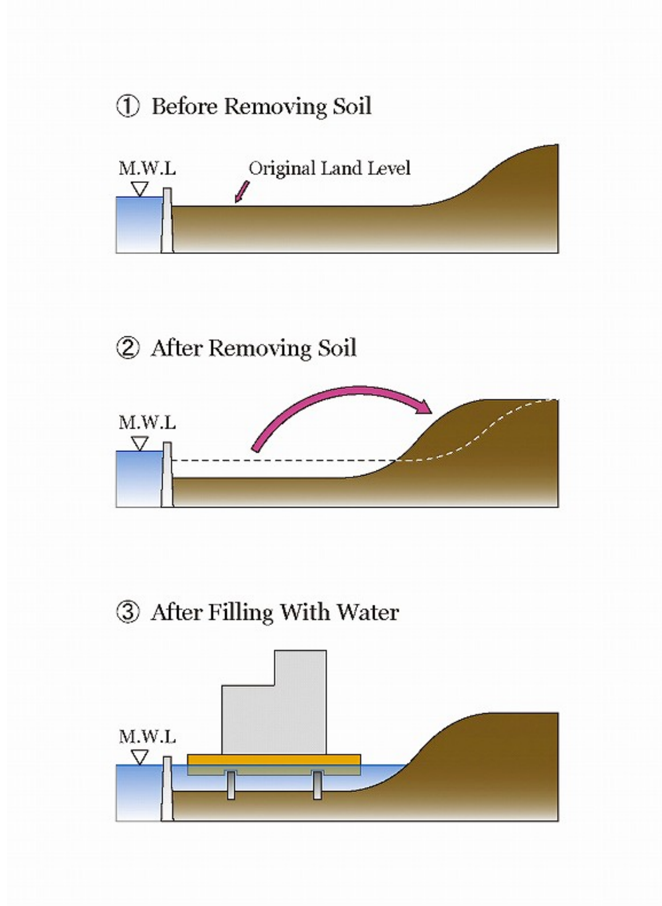

Fig. 2 Construction Scheme for Water City

Step 3 Floating foundations constructed at shipbuilding facilities are towed to their sites. In principle, as is shown in Fig. 2③, the floating foundation keeps itself afloat but the proposal calls for what is known as the "Soft Landed System." In this system, the floating foundations are semi-supported by piles constructed underneath.

Step 4 Finally, buildings are constructed on the floating foundations inside the man-made waterfront. Roads and bridges are constructed to allow passage between the floating foundations and the land. A waterfront development for an urban area in low-lying land can be a flood prevention measure by itself because the target area is able to function as a subsidiary pool. The following items are the objectives of the waterfront construction: (1) To prevent a flood from the rivers, due to storm surge, tsunami, levee break or sea-level rise in the future. (2) To protect the community from localized heavy rain caused by global climate change (with the aim of providing relief of low ground areas). (3) To improve the urban environment by reducing the heat load of the city (a counter-measure for the "summer heat island" effect). (4) To replace automobiles with waterborne transportation. (5) To restore the water cycle system by filling underground area with water (to

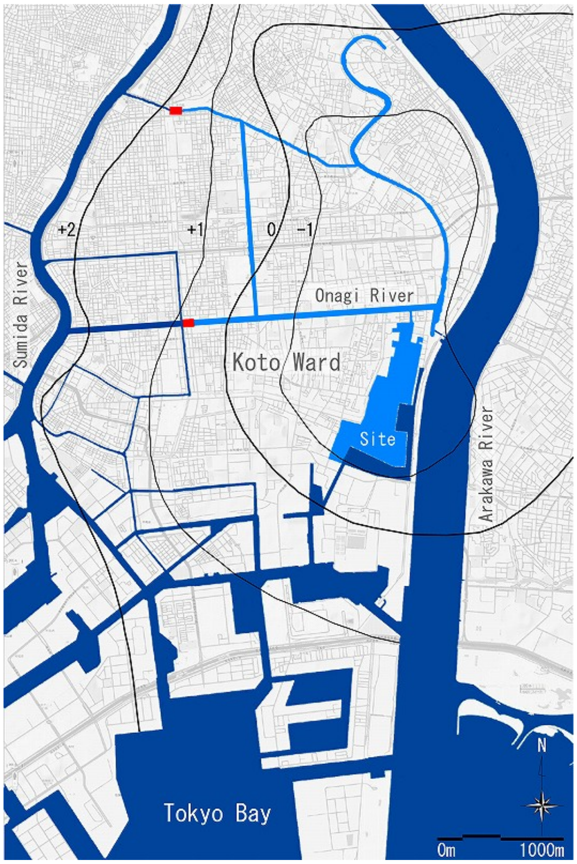

Fig. 3 Site for Water City, Koto Ward

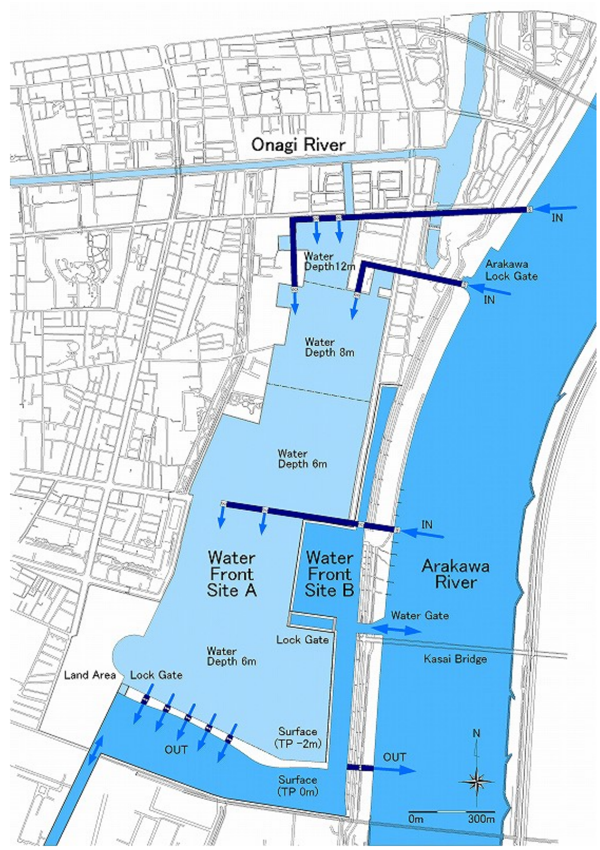

Fig. 4 Two Kinds of Waterfront Site

maintain a supply of water in case of water shortages). (6) To install biotopes for the purpose of protecting aquatic organisms, thereby preserving the natural water environment. Furthermore, there are many other benefits to a water city in which all the buildings are constructed on floating foundations. The city is made safe against a large earthquake as the water cushions the structures from seismic shock. Also, water is readily available for firefighting while that for domestic use is secured even after a disaster.

III. WATER CITY PROJECT FOR KOTO WARD OF TOKYO

A. Outline of the Project Site

The project site, Koto Ward of Tokyo, is located approximately 3 km from the mouth of the Tokyo Bay and is located in a low ground district called the Koto Triangle between the Sumida River and the Arakawa River (See Fig. 3). This area used to be one of the most prosperous suburban industrial sites in Tokyo, and a substantial quantity of underground water was pumped up through wells during early 1940 and 1970, further encouraging land subsidence. Since then, the situation has remained highly critical. Today, two thirds of the total area of Koto Ward is lower than the average sea level of the Tokyo Bay, and the area as a whole is protected by a number of water gates, levees and seawalls. The counter lines of the vertical distance from about 1 m below the water surface of Tokyo Bay are shown in Fig. 3. In the area on the eastern side, where the project is planned, and where the ground level is even lower, the surface level of the water channels has been adjusted to 2 m below the average surface level of the Arakawa River. Under these conditions, Koto Ward depends heavily on tall levees (5 m or more above sea level) and boats in waterborne traffic travel between the Sumida River and the Arakawa River by way of lock gates. In September of 1947, Koto Ward had been completely flooded by the typhoon Kathleen. Moreover, Koto Ward area has some disadvantages in the landscape environment, such as soft soils on land and many canals/water channels in the area which makes this area easily flooded. And the project site in particular is characterized by narrow and disorganized streets with few parks giving the impression of random development. If a large earthquake or fire were to occur, the situation would become highly critical.

However, Koto Ward area used to be one of the most prosperous suburban residential sites in Tokyo. So private developers have been promoting condominium development in Koto Ward and thereby speeding up the demographic expansion. The population in 1957 was 300,000, but this had grown to more than 480,000 by June of 2013. The total land area of Koto Ward is 39.8 km^2 and its population density is 11,000 persons /km^2. There are huge warehouses of logistics companies side by side with private dwellings in the residential areas.

B. Design of a Man-made Waterfront

The waterfront to be developed in this Koto Ward project is divided into two sections (See Fig. 4), so that the operation of flood prevention measures can be carried out in two phases. Waterfront Site A (0.85 km^2) on the inland side is completely isolated from the Arakawa River and the Tokyo Bay. At present, in the east area of Koto Ward where the ground level is very low, the surface level of the water channels is adjusted to two meters below the average surface level of the Arakawa River. Waterfront Site A is designed to link those channels, including the Onagi River. The connection with the Onagi River will enable the free and extensive transportation of people and goods throughout the community regardless of tide level. Waterfront Site B (0.34 km^2) is a narrow inverted L-shaped area. Currently, the section is separated from the adjacent Arakawa River by high levees. Boats travel to and from the Arakawa River by way of water gates that remain open except during emergencies such as the tsunami transmission. Although the water level in Waterfront Site B is directly affected by the tide level, its merit is that boats are able to move to and from the Arakawa River and the Tokyo Bay freely without passing through a lock gate. Waterfront Site A takes care of rainfall in the low ground areas of Koto Ward while Waterfront Site B cushions Waterfront Site A from any direct impact that may occur when the Arakawa River overflows.

In order to prevent water from stagnating in Waterfront Site A, an artificial current is created with water drawn from the Arakawa River. First, water is conducted from the Arakawa River to the north area of the project site through underground aqueducts. The water in Waterfront Site A eventually discharges to Waterfront Site B driven by 5 axial flow pumps embedded beneath the southernmost promenade (built on the partition wall between Waterfront Sites A and Site B). Because Waterfront Site B connects directly with the Arakawa River and the Tokyo Bay, the water level in Waterfront Site B is almost at sea level and is therefore hardly affected by the discharged water. The quantity of water discharged to Waterfront Site B by the axial flow pumps is subject to seasonal change, depending on seasonal increases due to heavy rain for example. In the case of a rainfall of 50 mm/h, the overall rate of rainfall in 1 km^2 is 13.9 m^3/s (no more than 28 m^3/s in case of 100 mm/h rainfall), which is within the capacity of 5 axial flow pumps (12 m^3/s per pump). Therefore, a measure against localized heavy rain can be carried out within the site. Solar energy supplies the power to activate the pumps and other facilities. It is possible that the flow of water to Waterfront Site A may stop for certain period of time due to a shortage of electric power, however, no large problem is anticipated as a result of this. In fact, the use of solar energy as a power source to purify and pump water takes advantage of natural energy and thereby shares a common viewpoint with the windmill system used in the Netherlands to drain excessive inland water.

C. Water City Planning

The water city plan for this study covers an area of approximately 2 km from north to south and between 0.5 and 1.0 km east to west, with a total land area of approximately 1.25 km^2, although the that of 0.185 km^2 in the study of Oceans'11 (almost 7 times larger). The population is nearly 27,500 people and the area consists of 12,600 households (previous study indicated nearly 4,300 people and 1,850 households) and there is a population density of 223.6 persons /ha. The plan includes the development of a mid-to-high-rise housing area (approx. 560 persons /ha) and a waterfront as an open space that occupies nearly half of the total area being developed (625,000 m^2 or 22.7 m^2 /person). The planned population, which is set at its current size between 27,000 and 30,000 people, is three times the size of that of its neighboring communities (8,000 to 10,000 people). In accordance with these demographic proportions, the project site constitutes a mid-sized city that will require three elementary schools and one junior high school. In addition to its residential functions, various urban facilities are being taken into consideration to enliven the city (See Fig. 5). These include: (1) a shopping complex necessary for comfortable living, (2) an aggregated industrial site for small workshops, (3) an aqua resort space along the Arakawa River, and (4) an office complex (but for Oceans'11 we limited the urban function to just residential facilities).

With the integration of waterfront development into the city planning, the project site will become a comfortable and safe water city that benefits from the aquatic environment.

Fig. 5 Various Urban Facilities in Water City

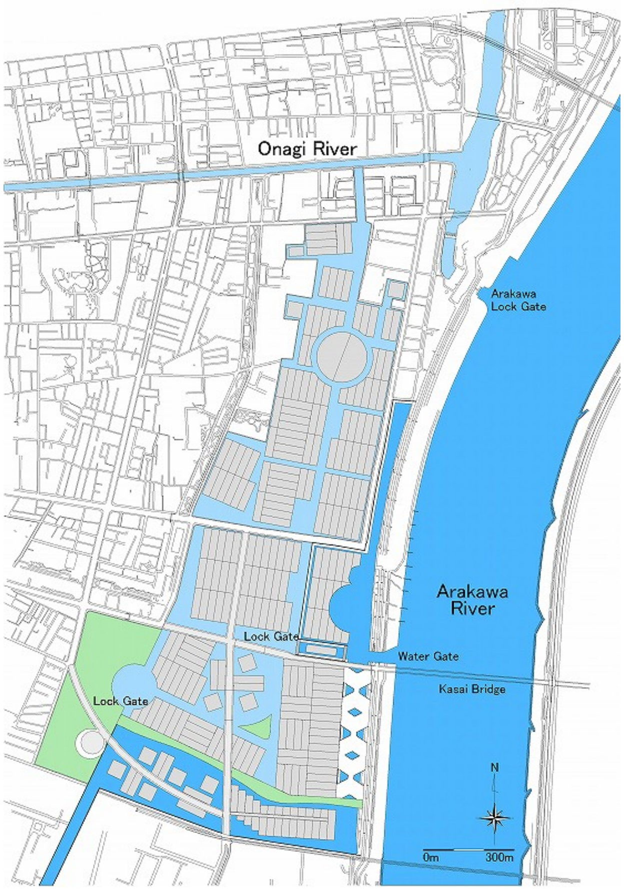

Fig. 6 Site Plan of Floating Module Units

One of the major merits is the restoration of waterborne transportation that will ease road traffic congestion. Specifically, the water channel proposed by this plan connects with the Onagi River in the north and with the commercial district near the Minami-sunamachi Station on the Tokyo Metro Subway in the south, which is a gateway to this project site. The Onagi River, extending north in this project site, links with the Sumida River by way of the Ogibashi lock gate in the west and with the Arakawa River by way of the Arakawa lock gate in the east. This connection facilitates the operation of waterbuses as a more extensive and convenient traffic measure. Steering further down through the south lock gate of this channel, boats will finally enter the Tokyo Bay from the Shinsuna water gate.

D. Design of Floating Foundation

Most floating foundations, which support the structures of a water city, comprise large numbers of floating modular units. More than 130 modular units and other floating foundations are used for this project (See Fig. 6) while only 44 modular units were used in the study of Oceans'11. The steel barge-type floating foundations were chosen because of their outstanding performance in the Mega-Float Project in Japan. The prototype length for floating modular unit was fixed at 100 m, since most street blocks in cosmopolitan cities are designed at approximately 100 m in length, and this is considered to be a comfortable distance for people to walk. The width of the unit was fixed at 25 m so that the modular unit can be built even in mid-to-small scale shipbuilding docks, and also because the number is a divisor of 100. According to the calculation of water discharge under the conditions of a 3 m draft, the total depth of the floating modular unit is 4.5 m, the buoyancy force of a floating modular unit to be supported is 7,500 t (or 73,500 KN; dead weight of floater plus additional facilities). These were the criteria that dictated the design of the floating modular unit. A bird's-eye view of the medium-sized apartments and low-rise housing constructed on floating foundations inside the man-made waterfront is shown in Fig. 7. The roads shown in this picture are also built on floating concrete structures mounted on concrete piles so that the roads can float in the case of flooding.

Fig. 7 Apartments and Private Houses on Floating Foundations

Medium-sized apartments with about 30 residences (2,131 t or 1,440 m^2) and approximately 12 low-rise private houses (3,560t or 2,400 m^2) can be built on a single floating modular unit with a buoyancy force of 7,500 t including roads and open spaces. Then the total load with live load of the apartments and private houses brings the total weight to 5,961 t. The load of 1 m^2 of a light-weight reinforced concrete building was calculated as 1.48 t/ m^2 in the fundamental study and is used in these calculations. On the other hand, the figure of 0.167 t/ m^3 was used for the calculation of the approximate dead weight of a floating modular unit made of steel as estimated from data provided by the Mega-Float Project [5]. The live load of items such as trees, asphalt and cars is assumed as 860 t in this study. Furthermore, since this live load varies depending upon quantity, materials and so on, the design enables the adjustment of one fifth of the total live load by regulating the volume of ballast water (the total volume of ballast water in each floating modular unit is 1,250 m^3) inside each floating modular unit. On the other hand, since approximately one tenth of the total load is supported by several concrete piles,

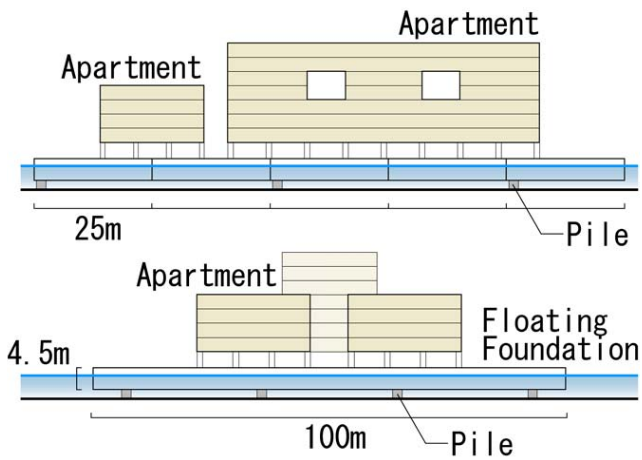

Fig. 8 Elevation View of Floating Foundation consists of 5 Modular Units

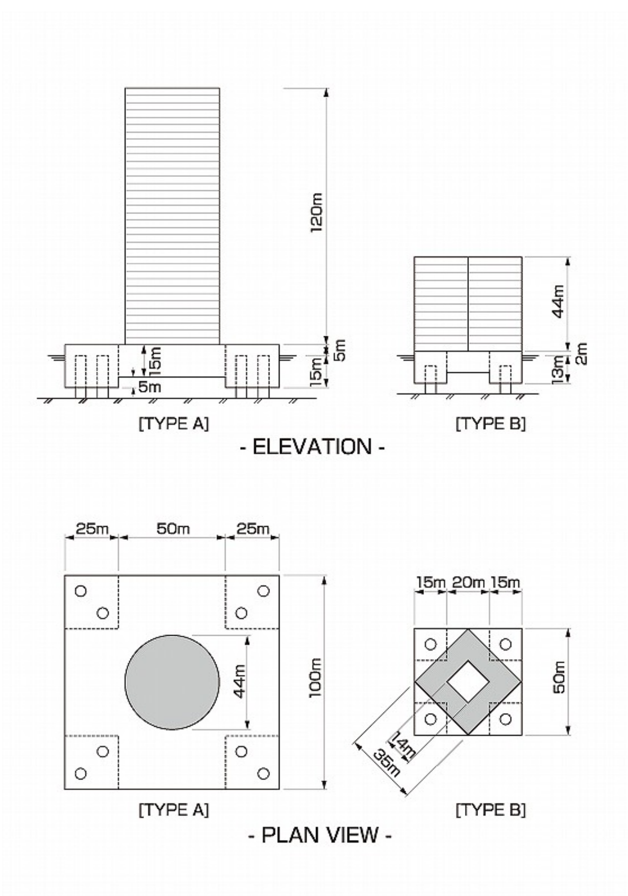

Fig. 9 Two Kinds of Arrangement Plans for High-rise Condominiums

the final total load of one floating modular unit comes to 8,250 t (7,500 t is supported by the buoyancy force of the floating foundation while the supporting piles add 750 t). The elevation view of the floating foundation consists of 5 floating modular units is shown in Fig. 8. The more details of this floating foundation consists of 5 modular units have been demonstrated in the paper of Oceans'11.

In addition to the prototype floating modular unit system, another two types of the super-high-rise and high-rise condominiums founded by different types of floating foundations are introduced in this paper and are shown in Fig. 9. Although the super-high-rise buildings have some merits such as their high efficiency performance in economics and in functions, curious minds ask if such tall structure on the floating foundation is possible. In general, for the construction of super-high-rise building, larger static stability is required for the floating foundation. This means that a larger water plane area with shallow draft should be designed for the floating foundation and larger inside space obtained (See Fig. 10). For secure, larger space is allotted to the water ballast tanks. In this floating foundation, four water ballast tanks are located at each of the four edges of the square-shaped floating foundation. The rest of the inside space is used for shopping mall, restaurants, library, banks, post offices and so on. The heights of super-high-rise and high-rise buildings are respectively 120 m (34 stories) and 44 m (11 stories) from the deck of floating foundation while the length of the square-shaped floating foundations, made of steel, is 100 m or 50 m each (See Fig. 9). Again these two types of floating foundation are also supported by several piles with additional weight of ballast water being loaded inside the floating foundation, so that the floating foundation stays in the same location until the water surface rises more than 1.5 m, this being a value close to the normal tidal height.

E. Feasibility Studies from Engineering Aspects for High-rise Floating Complex

First of all, the floating foundation in flooding condition due to heavy rain, storm surge and tsunami is discussed. The height of tsunami at the projected area has been estimated by Japanese authority as 2.5 m at most which is a somewhat lower value because the water city is to be located inside enclosed sea surface of Tokyo Bay. Meanwhile, the proposed

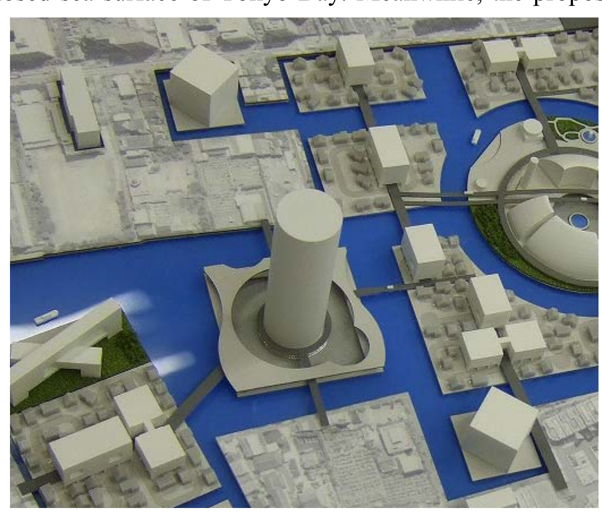

Fig. 10 Super-high-rise Condominium on Larger Floating Foundation

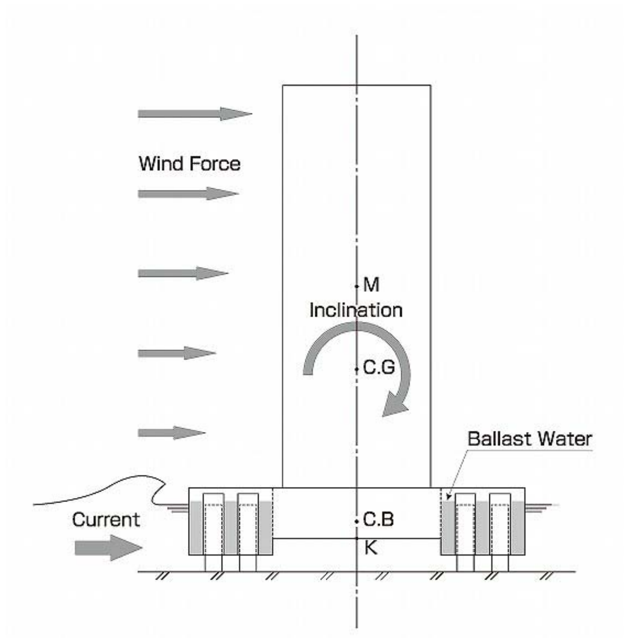

Fig. 11 Sectional Elevation of Super-high-rise condominium

water city may avoid direct hits from tsunami since the location is surrounded by the sea levee of 5 m high with water gates being found along the Arakawa River. Then, for the vertical increase in water depth, it can be assumed that the water level has increased by 2.5 m at most (changing the water depth to 22.5 m from 20.0 m). In this condition, the floating foundation of the super-high-rise building Type A rises 1.0 m (not 2.5 m) and the freeboard of the floating foundation becomes 3.5 m from 5.0 m, with the supporting piles being detached from the rubber fender of the floating foundation. In such case that the water level rises more than 2.5 m, the floating foundation moves up more and the deck does not sink at all. This means that the water city is completely secure against rising waters such as flooding.

In case of a tsunami, the concerns as to drift force due to the horizontal tsunami force acting on the floating foundation may be voiced in addition to the vertical increase in water depth. According to computation by the drag force equation, the maximum horizontal load for tsunami against the floating foundation and supporting piles is estimated as 15,690 t (or 153,750 KN) based on the assumption that the horizontal velocity is 10.0 m/s observed at the water depth of 10 m on land during the huge tsunami in the Indian Ocean in 2004. Here in above calculations of the horizontal natural load on the structure, we assumed the drag coefficient as 2.0 for tsunami and the projected area of the floating foundation is 1,500 m^2. Generally speaking, horizontal load of current due to tsunami on the floating platform of barge type is to be not too large because of the small aspect ratio of the floating foundation. In another words, the most tsunami flow passes through underneath of the floating foundation and then the floating foundation just rides on the tsunami flow and never let stop it. Moreover, the floating foundations are safe because that the floating foundations are protected by 3 m high levee located at between the Waterfront Site A and Site B and therefore the floating foundations inside Waterfront Site A are designed not be hit by tsunami loads directly and therefore 10 m/s is an unrealistic value for tsunami speed. In reality, the water depth gradually increases in vertical direction because that tsunami flows through some current flow valves located at the bottom site of levee when tsunami approaches.

As there are no effects expected from the waves and tides unlike in the open ocean waters, the main issue is earthquakes and strong wind besides huge tsunami. However, against earthquakes, since floating units are buffered from the full brunt of the tremor thanks to the dampening effect of water, they can be considered to be safer than structures that sit directly on top of the ground. The floating unit used in this proposal considerably minimizes the influence of earthquakes for two reasons. One is that water serves to dampen the platform motion caused by seismic motion in the horizontal direction. The other is that the natural period of vertical and horizontal platform motions become longer than that in air due to the increase in the virtual mass of the platform in water. The result is that the tuning between the earthquake and the platform motion is avoided.

Next, the maximum inclination due to the strong wind from typhoon in super-high-rise floating complex is obtained theoretically. The vertical location of center of gravity (C.G) for the super-high-rise condominium Type A with buildings, ballast waters and so on is calculated to be 49.14 m (KG) while the meta-centric height (KM) is 83.24 m (See Fig. 11). These values indicate that the floating foundation is quite stable against strong winds. In fact, when the design wind speed is assumed to be 50.0 m/s (10 minutes average value at 10 m height) which is more than 39.6 m/s, this maximum in Tokyo area having been reached during a typhoon in September of 1917, the approximate horizontal wind load and the heeling angle of the floating foundation are calculated as 15,639 t (or 153,262 KN) and only 1.77 deg., respectively, under free floating condition (without the effect of supporting piles) thus showing that there is a small effect generated due to strong wind. In the calculation, the drag coefficient for tall condominium of circular shape is assumed to be 1.2 and the design wind speeds at different height have been estimated by the one seventh power law (known as the Prandtl-von Karman universal velocity-distribution law) and are used for the calculation of wind heeling moment (1,190,000 KN m) acting on the super-high-rise condominium. The wind speed at the height of 115 m reaches 70.9 m/s according to the calculation. The restoring moment of floating foundation is obtained by the product of the GM value (34.10 m) and the displacement of the floating foundation (115,300 t or 1,130,000 KN) and are 38,535,000 KN m.

F. *Construction Scheme*

The floating foundations consisting of many standard modular units will be built inside the man-made reservoir. As for the first stage of construction procedure, several modular units are to be constructed at several factories. These are

Fig. 12 Towing Condition of Standard Floating Module Unit

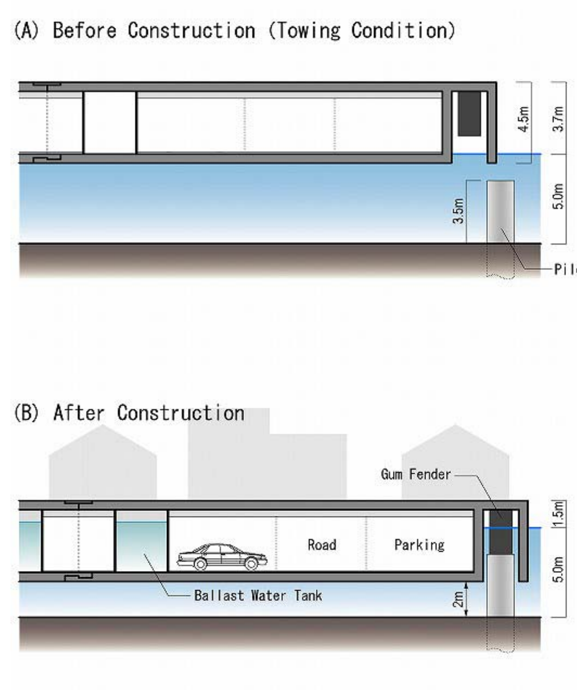

Fig. 13 Sectional Views of Before and After Construction of Floating Foundation

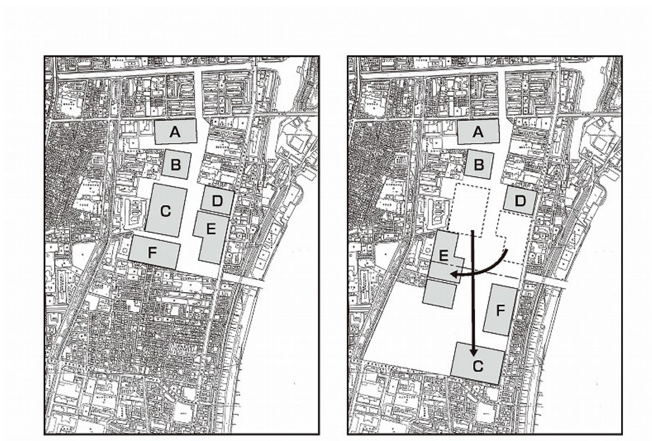

Fig. 14 Construction Scheme for Enlargement of Waterfront Area

towed to the location site (See Fig. 12). To reduce the construction period and to maintain structural quality, several modular units are constructed at multiple shipyards. Since a floating modular unit floats by itself, it can be easily moved freely in the horizontal direction in the man-made reservoir and, when connecting the floating modular units by welding and their supporting piles, vertical adjustment can be precisely controlled by changing the weight of the ballast water inside the floating modular units. This modular unit system makes it a very simple matter to change the whole size of a floating foundation at any time by adding or removing module units which had been tested successfully at open sea in the Mega-Float Project in Japan during 1995-2000. Fig. 13 shows sectional elevation views of two different conditions of the floating modular unit. In this figure, (A) indicates the towing condition of the floating modular unit. This is the lightest condition of the 0.8 m draft since there is no ballast water inside of floating modular unit. Fig. 13 (B) shows the floating modular unit with ballast water at the planned site after the completion of construction of all buildings. The draft of floating modular unit is 3 m in this figure and the piles support the floating foundation with a rubber fender located on the piles. The total weight of the floating structure is both supported by buoyancy force and several supporting piles underneath of the floating structure.

We had planned the water city at only the eastern side of Koto Ward which was assumed to be the first stage of the entire water city plan in the paper of Oceans'11. When the additional construction of water city is required for the enlargement of water city, then the additional land area next to the first stage would be excavated and filled with water. Fig. 14 shows the scheme as to step-by-step procedure for enlargement of man-made reservoir. Here the additional floating foundations would be constructed at the shipyards and towed to their sites in general. At the same time, the relocation of the existing floating foundations could be necessary as the new stage of the water city. In this situation, the existing floating foundations should not be taken off and can be reused again. So the floating foundations are to be reused several times on the condition that a water city is sustainable and that there will be a reduction in CO_2 emission while constructing and maintaining the city. In addition, due to the movable nature of the floating structures, the water city can easily be restructured to meet changing needs.

IV. CONCLUDING REMARKS

Many big cities are built on large areas of low ground below sea level and are potentially hazardous areas that carry a high risk of natural disasters due to their location close to seas and/or rivers. By applying lateral thinking, the weakness inherent in such locations can be converted to strength, offering protection against water disasters by rethinking the way people live in such areas, i.e. by constructing buildings on floating foundations in calm man-made reservoirs rather than on land near the sea. The objective of this paper is to introduce a farsighted project for a waterfront development in a city area found on low ground, where the social infrastructure is built on floating foundations that will not submerge due to rise in the water level. This provides a safe and comfortable living environment. The current study presents concrete details by applying the concept to a hypothetical water city plan for Koto Ward, Tokyo.

In this paper, we clarified from the study on Koto Ward project that it is possible for a safer water city based on the floating structures against most natural disasters to be constructed, likely useful for some future feasibility studies from the engineering point of view. Here, we suggest excavation of lower-lying land areas to realize a large reservoir in the middle of cities to place a semi-floating structure therein, also seeks to produce a man-made foundation as well as artificial structures atop it, in order to make effective use of the space above the body of water and there produce a living space on the floating foundation (See Fig.15). This idea emanates from offshore technology. Although floating structures suffer from non-linear high waves and many kinds of currents in the open sea, the sea-keeping capability of those inside calm man-made reservoir seemed to be excellent and stable. We therefore had noticed we could use floating structures as the different solution against disastrous flooding due to global climate change and sea level rise. Though most people worry about capsizing, sinking of floating structures and other phenomena seen at sea in general, we can easily persuade these people simply by explaining that in our case the water depth is close to the bottom of floating foundations. We therefore strongly recommend that this offshore technology and its knowledge of the floating structures be applied to architecture and buildings on land. It seems that we, as offshore engineers, have the responsibility of explaining and convincing people in general and legal entities in particular that the technology of floating platform has become established in the ocean engineering field, thereby safe, trustworthy and reliable. We should seriously consider the contribution for civil purposes that an application of very large floating structure (VLFS) can make now to realize a prosperous future [6].

Fig. 15 Bird's-eye View of the Water City of Koto Ward, Tokyo

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