A Proposal for a Floating Urban Communities in the Man-made Inlets

－Toward a City Construction as a Countermeasure against Natural Disasters－

Toshio Nakajima[a], Motohiko Umeyama[b]
[a] *Institute of Physical and Chemical Research (RIKEN), Japan*
[b] *Tokyo Metropolitan University, Japan*
tnaka@ttp-r.dlenet.com

Abstract: In the next 100 or 200 years, the rising sea levels due to the global warming and the increased frequency of extensive natural disasters caused by the global climate change will bring about serious problems especially for coastal and riverside areas located in low ground below sea level. In this paper, a new concept is introduced that utilizes floating foundations to create an urban community base in artificial inlets and/or basins to attain a sustainable city environment for a prosperous future. This paper proposes the establishment of secure bases to safeguard against any risk brought about by future natural disasters, especially flooding due to heavy rain, storm surges caused by typhoons, tsunamis, earthquakes and so on.

Keywords: floating, sustainable, waterfront, mega-float, soft-landed, low-lying land/

1. Introduction

All over the world, strenuous efforts have been made to restore the global environment and create a sustainable society. Architects, civil engineers and construction companies have also helped to play their part in this by incorporating reduced energy consumption into their designs, by using recycled construction materials and so on. In spite of the widespread movement to diminish greenhouse gases such as carbon dioxide in order to avoid the consequences of global warming, we have yet to see any substantial reward for these efforts. One of the most visible results of global warming is the rising sea levels and one now wonders if it will be possible to stem the tide of this critical situation in the future or not.

According to the newest report by the Intergovernmental Panel on Climate Change (IPCC 2007), the global average surface temperature increased approximately 0.74℃, and the global average sea level rose 0.12 to 0.22 m in the past hundred years (1906-2006). The IPCC estimates that the average global temperature will rise 2.4 to 6.4℃ by the year 2100, relative to 1990, and the amounts of sea level rise will range from 26 to 59 cm. This sea level change is primarily due to thermal expansion of ocean waters and loss of mass from melting glaciers and ice caps. The corresponding study of global warming by the U.S. Environmental Protection Agency concludes that there is a one percent chance that the global sea level could rise by more than 4 m in the next two centuries. Numerous investigations confirm that the indirect effects may be more significant than the direct effects by global warming in this century: rising sea level inundates low lands, erodes beaches, and increases the salinity of rivers and estuaries. Climate change also affects the frequency and intensity of some extreme phenomena. The extent and severity of storm impacts may increase as a result of regional climate changes.

At this point in time, it is necessary to prepare for the worst scenario in which large areas of land will sink under the sea. In addition to this, there is a distinct danger that the speed of sea level rise may accelerate. Due to the centrifugal force created by the rotation of the Earth, the areas likely to be hit first by such a disaster will be in the equatorial zone. Then gradually, this will spread to low-lying lands adjacent to the sea all over the world. Compounding the situation is the risk of disaster to urban areas that is growing year by year due to the increased frequency of massive tsunamis and unexpected storm surges brought about by the huge typhoons resulting from the unnatural climate changes.

2. Recent circumstances and problems in big cities

During the past several decades, assisted by government investment in public works, urban construction such as houses, apartments and other buildings and urban infrastructure, such as roads, railways and so on have continued unabated. These projects have been carried out with the purpose of encouraging economic expansion in an attempt to meet the demands of the rapid growth, both in population and economics of this country. Nowadays, there is a movement against these policies since they involve fruitless construction projects, with the purpose of making way for a more prosperous future. Looking ahead 100 years or more into the future, the keyword in urban construction projects is undoubtedly “sustainable.” This keyword covers all the actions of mankind, and it is necessary to make an effort to build cities that are not only capable of withstanding global environmental disaster but that at the same time place the minimum burden on the environment.

Many coastal areas near cities that have hitherto been occupied by factories, warehouses and so on have gradually been turned into comfortable waterfront amenity zones. The Tokyo Metropolitan Government is also making an effort to remodel waterfront areas as vital and active zones with such projects as the Canal Renaissance Project and so on.

However, it cannot be ignored that there are cities that face water disasters such as water shortages arising from a reduced rainfall in dry summers and flooding from heavy rain. In many cases, water floods come about because the land in urban areas is almost completely covered with concrete and asphalt, preventing rain passing through into the underlying soil. This situation also brings about the problem of overheating in cities that we call the “summer heat island.”

Furthermore, there is a danger of a massive and destructive earthquake hitting the Tokyo area in the near future. The biggest danger from earthquakes is from fires breaking out following a seismic disturbance. This was shown at the Hanshin-Awaji earthquake in Kobe City in January 1995, where it was almost impossible to bring the fires under control because of the damage to the water supply and the electric power supply resulting from the earthquake. And thereafter, the refugees suffered from a shortage of fresh water for drinking, washing, ablutions and so on. The lesson learned from this is that a supply of pure water must be given the highest priority in times of natural disasters.

3. Natural disasters and countermeasures

In December 2004, a huge tsunami arising from a large earthquake offshore of Sumatra killed more than 160 thousand people and destroyed housing over a huge area near the shore. The world was shocked to learn that the maximum height of the tsunami was greater than four meters. On the other hand, the El Nino weather pattern resulted in several huge cyclones for the 2004-2005 season in the Southeast Pacific around and east of the date line. In the course of four weeks in February 2005, Cyclones Meena, Nancy, Olaf and Percy have struck the Cook Islands. As these cyclones were stronger than Cyclone Sally that is reputed to have caused the most damage to Rarotonga in the past, the Government was well prepared for the storm and the flood, setting up evacuation shelters around the island. Following this, in August, about 80 % areas of New Orleans sank under the sea as a result of the devastation caused by hurricane Katrina and more than 1,600 peoples were killed. The storm surge brought about by this catastrophic hurricane of Category 5 destroyed seawalls and the subsequent delay in the repair of the old seawalls made this one of the worst disasters ever to be experienced by the U.S.A. The destruction was so bad that, two years later, 66% of the original inhabitants who had been relocated elsewhere had still not returned, adding further delays to the reconstruction of the city. According to the Yomiuri Newspaper of Aug. 31, 2007, only 19 % of bus system, 40% of schools and 57% of hospitals are recovered by now. The lesson to be learned here is that once the damage from a natural disaster goes beyond a certain point, it becomes extremely difficult to rehabilitate the local community.

In many places, seawalls protecting cities have suffered damage due to erosion and replacement or reinforcement has become necessary in spite of the prohibitive costs required. Taking a long-term view, considering the inevitable rise in sea levels, the height of seawalls must be increased, yet, it is unrealistic to propose the replacement or reinforcement of all the seawalls in Japan because of the limited public funds available and the fact that the number of infrastructures such as dams, bridges and so on requiring replacement or reinforcement in Japan is simply too great. On the other hand, the likelihood of the magnitude of natural phenomena continuing to increase year after year due to future climatic changes cannot be ignored. What can be done to develop the sea and riverside areas to safeguard against water disasters considering the next 50 or 100 years? It is vital that an alternative solution be found that will produce a higher degree of safety for the reduction of disasters.

4. Outline of man-made inlet and floater

4-1 Concept of proposal and arrangement of the system
Scope and plan of proposal:

An example of a low-lying waterfront zone at sea level near an ocean and/or river is presented below. The plan is to change the potential danger in this site to produce an area safeguarded against the natural disasters mentioned above. An outline of the process follows:

Step 1 An area approximately half of the site is excavated to a depth of several meters and the topsoil removed. The topsoil removed from the site is to be relocated in order to raise the urban site above sea level(See Fig.1① and Fig.1②).

Step 2 To prevent the destruction of the bank, concrete levees are built around the edges of the bank. These are filled with fresh water until the water level behind the levee reaches sea level, to construct a man-made inlet and/or basin.

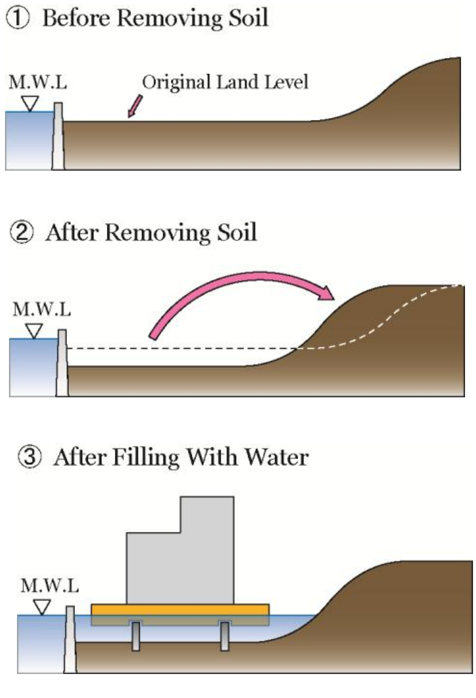

Fig.1 Construction Scheme for the Proposal

Step 3 A canal is constructed to connect the man-made basin to the sea and/or the river and a water gate built at the entrance of the canal. The canal is to be used for the passage of seagoing vessels and for the entrance of the floaters upon which structures will be built inside the man-made basin.

Step 4 Finally, buildings are constructed on the floaters inside the man-made basin. Road bridges are constructed to allow passage between the floaters and the land(See Fig.1③).

In general, the larger the area of water surface provided, the more comfortable the amenities will be. However, the water surface does not necessarily need to be larger than the surface area of the city. In very large metropolises such as Tokyo, the water surface can be much smaller (See Fig.2).

The floater in the proposal is a barge type construction, similar to that used in the Mega-Float Project that was carried out in Japan between 1995 and 2000. The material used in the construction of the floater may be concrete, steel or FRP (Fiber Reinforced Plastic). In principle, the floater floats by itself but the proposal calls for what is known as the "soft landed system." In this system, the floaters are semi-supported by support piles constructed underneath them. The buoyancy provided by the floaters serves to lighten the load on the support piles. Laterally mounted support piles connected to the sides of the floaters feature rubber fenders that assist the control of the horizontal excursion of the floaters(See Fig.3).

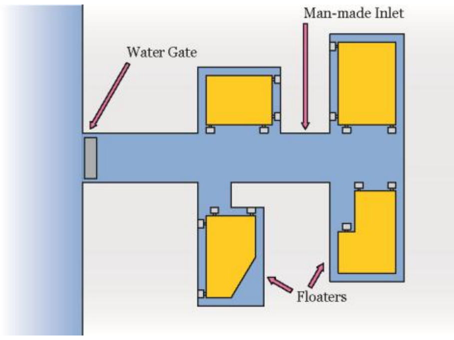

Fig.2 Concept of Man-made Inlet with Floaters.

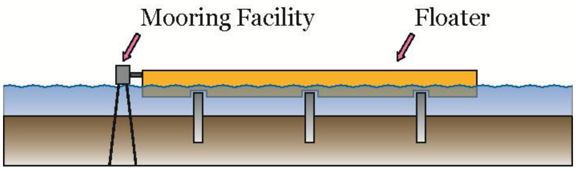

Fig.3 Arrangement of Floater System.

4-2 Effect of various natural loads and stability of floater

The floater system 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 horizontal platform motion becomes 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.

It is estimated that the wave effect will be minimal due to the small fetch length in the closed inlet and that the danger of strong winds causing the floaters to lean will be negligible due to the support provided by the underwater piles.

With sufficiently large floaters, the provision of supporting piles becomes unnecessary. In this situation too, the danger of strong winds causing the floaters to lean is quite small, since the metacentric height of a floater with a large water plane area is very large and thereby a high degree of stability is ensured. On the other hand, any motion influence caused by currents inside the closed basin will be kept to a minimum by the horizontally support piles underneath the floater. When there is an unexpected increase in water level due to the flood water from heavy rains and so on, the floater can easily change its position up from the soft landed condition (See Fig.4).

In conclusion, since the system proposed in this paper employs floating structures with support piles, the resultant structure will be perfectly stable against any natural loads.

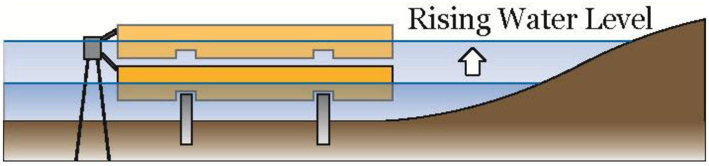

Fig.4 Various Conditions of Floaters Adapting to Changes in Water Level.

4-3 On the construction method

As for the construction procedure, each floater consists of several modules constructed at a factory. These are towed to the location site. To reduce the length of the construction period and to maintain structural quality, construction at the location site should be kept to a minimum. For the same reasons, it is also recommended that any buildings located on the floaters also be constructed at the factory.

Since a floaters floats by itself, it can be easily moved freely in the horizontal direction in the man-made inlet and, when connecting the floater and its supporting piles, vertical adjustment can be precisely controlled by changing the weight of the ballast water inside the floater (See Fig.5). The module unit system makes it a very simple matter to change the whole size of a floater at any time by adding or removing module units (Nakajima 2001).

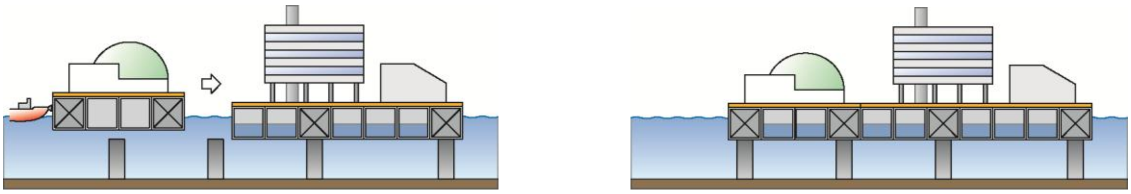

Fig.5 Floater Construction.

5. Discussion

Many big cities such as Tokyo, New Orleans and so on are built on large areas of low ground below sea level known as zero-meter sites. These sites are potentially hazardous areas that carry a high risk of natural disaster 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 (floaters) in calm man-made inlets or basins rather than on land near the sea. Costs will not be prohibitive since it is cheaper to excavate soil in low-lying areas at sea level because the amount of soil to be removed is less. In addition, the extra soil obtained from these excavations can be usefully employed to raise the height of low-lying land.

Furthermore, the proposed bases will not only provide people living in such areas with protection against natural disasters, they will also furnish scenic and recreational areas where people can enjoy a comfortable waterfront life under normal weather conditions (See Fig.6).

Generally speaking, it is preferable for floaters to lie in fresh water than salt water. There are many reasons for this. Maintaining a reservoir of fresh water for such applications as flushing lavatories, fire fighting after earthquake disasters, and so on is undeniably necessary for life. Also, fresh water is relatively non-corrosive and therefore the life of building structures is longer than it would be in seawater. The reservoir can also be employed in conditions of drought during times where there is little or no rain. Taking a long-term point of view, it would be advantageous to employ an infiltration device to prevent salt water flowing into man-made inlets where they are located close to the sea. In addition, maintaining a reservoir of fresh water is a useful way to safeguard against any future water shortage in the wider local area.

Fig.6 Bird's Eye View of a Floating Urban Community in Man-made Inlet and/or Basin

In city areas, it is proposed that pedestrian walkways be constructed around man-made inlets to create areas of scenic beauty where people can enjoy a picturesque waterfront life. The heat problem in cities caused by the accumulation of hot air will be alleviated by the natural cooling action of air flowing over the water and the water channels called for in the plan will provide air tunnels to keep the air moving. The plan would also establish a waterway transportation system that would enable passage between floating objects and canals, rivers and even the sea, with the construction of man-made inlets.

6. Aspects of legislature and problems

In general, architecture and building law stipulates that all buildings must be directly connected to land. For this reason, even though the floaters make direct contact with land through piles below the water, the fact is that they are floating in water and so, it is doubtful that they will be admitted as part of the architecture or the building. It is equally doubtful that the whole water surface may be considered as building land or a building site for the reason that at one time, the site had originally been land. Of course, it may be possible that the whole area, including the water site, be admitted as building land in a case where the total water area is smaller than that of the total site. When the water surface is made available to all, it is possible that the local government may allow the water area to be treated as a public space.

In the case of the design of the floating structures, there exist several related laws such as architectural law, law covering the prevention and extinguishing of fires, ship design law, harbor law, the law of the road, the law of road transportation and so on (Nakajima 2000). The concrete application of suitable laws will be adjusted and decided on by several government divisions.

It is not known what problems exist concerning the legislature. The plan proposed in this paper has no direct precedent and, as such, is quite unusual. Discussions between legal authorities, local governments, architects and construction companies will need to be promoted in order to solve the problems of jurisdiction and legislation as a first step before any practical work can be started.

Acknowledgments

The authors are grateful to Mr. Kenzo Nakajima, a designer at Minoru Takeyama Architect and Associates for providing all illustrations for this paper.

References

[1] Nakajima, T. et al .(2001) On the planning of a very large floating structure: 16th Ocean Engineering Symposium, The society of Naval Architects of Japan, 221-228.

[2] Nakajima, T. (2000) On the architectural design approach of the upper side structure for very large floating structures (VLFS), Techno-Ocean 2000 International Symposium, Vol.Ⅲ, 629-632.

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Biography

Dr. Nakajima: He is a Special Officer of the Institute of Physical and Chemical Research (RIKEN), and was formerly an Administrative Director, Kobe Institute, RIKEN. He received the Dr.Eng. in Navel Architecture from the University of Tokyo in 1981. His research interests include seakeeping, design of floating structure, mooring dynamics, floating city and ocean system. He is a member of the council for Tokyo Port, Tokyo Metropolitan Government, a member of the Japan Society of Naval Architects and Ocean Engineers, and a member of Tokyo Society of Architects and Building Engineers.

Dr. Umeyama: He is a Professor of Civil and Environmental Engineering at Tokyo Metropolitan University. He received the Ph.D. in Ocean Engineering from University of Hawaii at Manoa in 1989. He was a research fellow at Delft University of Technology. Current interests encompass a broad range in ocean engineering, including water wave theories, storm surge, sea level rise and turbulent structure in wave and current co-existing field.