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PROPOSAL OF THE TSUNAMI COASTAL LEVEE AS STABLE AND SAFE DESIGN AGAINST THE UNEXPECTED MAXIMUM SIZE OF TSUNAMI FOR NUCLEAR POWER PLANTS

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INTRODUCTION

The author contributes to a stable and safe design of nuclear power generation plants by applying special tsunami coastal levees with a new cross-sectional concept for embankments, which keeps stable and collapse free for any unexpected tsunami against nuclear power station (NPS). The new design turns from the probabilistic risk rating system for tsunami to deterministic design. The no-collapse bank protects the back side of NPS reactors from the destructive power of the tsunami to the NPS facilities and inundation of electric equipments, which have caused all loss to control the NPS nuclear reactors and have resulted in melt down with explosions of the buildings.

The social demand to cope with the tsunami disasters which can be severe human-life risks (Figure-1) caused by un-expected size of wave heights, that are larger than the designed for embankments. This issue has been brought out by the nuclear crucial accident at Fukushima No.1 nuclear power station. The author proposed cross-section forms of new type of coastal levees without collapse (Figure-2) but stable cross-sections which result in the concept of no probabilistic design but deterministic specification. The author emphasizes that the benefit to use sea-shore as the daily green park at the nuclear power plant comprises a superior convenient usage in the working environment in the nuclear power plants.

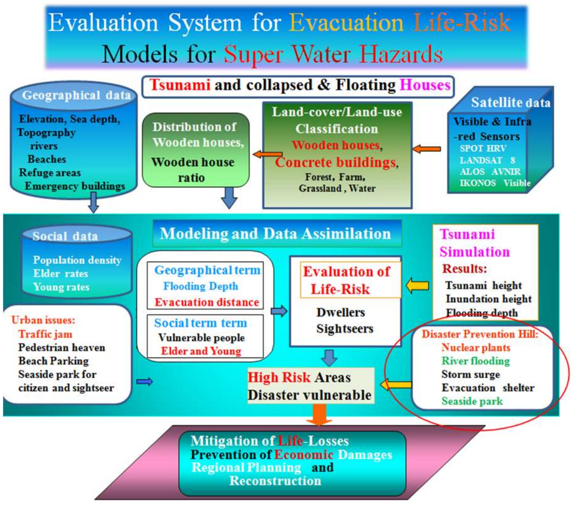

Figure 1 Flowchart for Multi-purpose risk assessments and embankments for super water disasters against tsunami-inundation, storm surges, river-flooding.

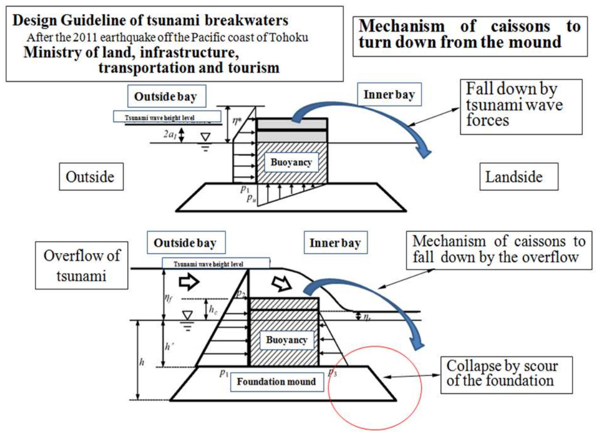

Figure 2 Traditional concepts for designing the tsunami breakwater are shown in the figure with the mechanism of collapse by the wave forces. The Japanese ministry of land, infrastructure, transportation and tourism provides the design standard, which relates to the new caisson-embedded bank.

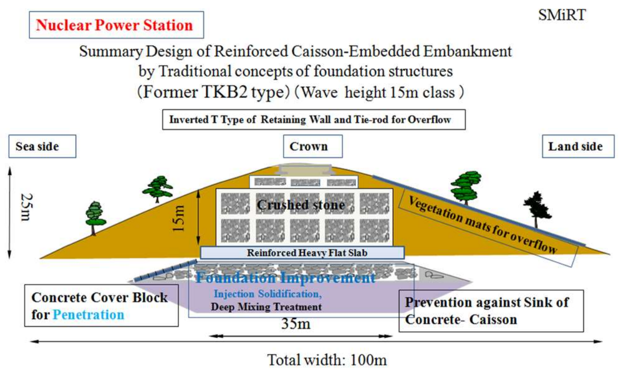

Figure 3 Proposed Stable caisson using traditional foundation with large broken stones for the settlement for big caisson loading over the case of feasible sea bottom such as clay. This design was commonly applied so many break waters in the severe areas of wave height facing open oceans in Japan. However, water penetration is consederable because of long period of tsunami waves.

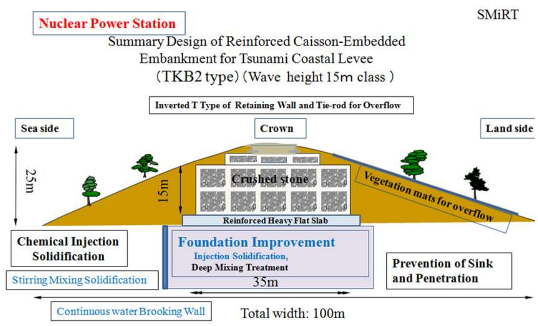

Figure 4 No-collapse stable cross section of proposed embankment with foundation improvement and impermeable wall to prevent penetration of sea water under the bottom of the embankment. The foundation improvement by stirring and mixing solidation stops the intrusion throgh the bottom into the areas of NPSs and also to prevent the sink of the levee.

THE FIRST STEP FOR DIRECTIVE DISCUSSIONS

The social demand to cope with the tsunami disasters which can be severe human-life risks caused by un-expected size of wave heights, that are larger than the designed for embankments. This issue has been brought out by the nuclear crucial accident at Fukushima No.1 nuclear power station. The author proposed cross-section forms of new type of coastal levees without collapse but stable cross-sections which result in the concept of no probabilistic design but deterministic specification. The author emphasizes that the benefit to use sea-shore as the daily green park at the nuclear power plant comprises a superior convenient usage in the working environment in the nuclear power plants.

Way of Thinking about the Bank Cross-Section for the NPSs

The author designed the lift pressure from beneath the former surface of the caisson by covering mound rocks using square blocks. On the other hand, the support strength of the solidification is enough by section stirred holes which are drilled and stirred holes which penetrates the foundation soil. However, some leaks of water are presumed between gaps both routs of consolidated soil of spherical shape and from stirred holes. The consolidated wall to stop the water penetration by the stirred sheet piles is necessary for the sea-side like the example shown in Figure-4. The aggregated form composed of sphere sand stirred sheet piles is the solidification by the chemical solution of infused and stirred consolidation.

Proper Application Sites for New Levees

The first question for new levees is where the highest regions of tsunami inundation in Japan, that is the most required countermeasure against the inundation for nuclear power plants. The author has chosen several corresponding sites for tsunami risky areas in the table-1. The highest risky plant will be Hamaoka NPS plant.

Table-1 Important characteristics of Nuclear Power Plants from Tsunami View-Points

No.	Characteristics of Power Plants	1	2	3	4	5	6	7	Priority
1	High **tsunami** Inundation	Higashitoori	Onagawa	Fukushima-F	Toukai	**Hamaoka**			**-1**
2	Important sizes of **huge plant** sites	Fukush-Futaba	**Kashiwazaki**	Hamaoka	Takahama				1
3	Disadvantageous **geography** （fasing)	Higashitoori	Fukus-Futaba	Toukai	**Hamaoka**				-1
4	Risks of near **highly populated** areas	**Toukai**	**Hamaoka**	**Takahama**	Genkai				**-2**
5	**New planning** sites without restrictions	Ooma	**Higashitoori**	Fukus-Namie	Kaminoseki	Shimane2	Mihama		1
6	**Power Supply** from National Policy	Tomari	**Onagawa**	**Kashiwazaki**	Hamaoka	**Takahama**	Shimane	Sendai	**1**

Author's view for **safe and primary goals : Onagawa, Kashiwazaki, Hamaoka, and Takahama.**

Important Huge Size of Nuclear Plants

The author proposes the sight candidates should be Hamaoka, Fukushima-Futaba, Onagawa, and could be the biggest plant sites of Kashiwazaki-Kariwa near Niigata City and Tokyo, in addition to Takahama near Kinki economical society accompanying surrounding dense population with water resources from Biwa Lake including for the safety of Osaka City.

Safety Design by Multiple Defences

If the pre-existed cross-sectional structure couldn't connect each other into reinforced and armed unit body of levees, multiple defence designs are only one way of the solution for the national safety for the whole Japanese society in main severest nuclear plant sites under the highest wave-height conditions. Both the construction of the stable type of new levee in addition to pre-constructed counter measures is the answer for the fundamental design policy for multiple defences against tsunami inundation and accompanied disasters.

Usual Reclamation History of Old Inner Part of Breakwaters

In Japan so many ports and harbours have been reclaimed because of large ships are launched due to huge container-ships emerged in decades. The inner sea water was buried to land for warehouses and breakwaters are turned to quays with new or shifted breakwaters off-shore of the port in the deeper sea areas. The port should be renewed to the new concept of the plant system design. On the cases of the most important and plural NEP plants, the reclamation and new break water are historically normal also for new concept of multi-defence countermeasures against tsunami inundation.

NEW NO-COLLAPSE EMBANKMENT

The author has proposed a stable sectional structure of stable levee against any unexpected size of tsunami without no-collapse to keep safe the NPS plants behind the bank. The proposed caisson-embedded bank enables a deterministic security-design by simplifying from the probabilistic risk evaluation methods to design the cross-section structures against the tsunami inundation.
The basic requirements in the abnormal range of levee design that suggests bank's cross section to the possible new coastal levee so that the NPSs keep safe to endure to waves by unexpected tsunami and also does not assume a severe accident of NPSs. The building structures for reactor containment vessels and control facilities in the NPS plant are kept stable without the severe accident (a natural hazard rank, T6). The levees never collapse even if the tsunami waves are higher than the typical case of Fukushima Daiichi Power Station, whose accident was caused by the East Japan Pacific off shore earthquake (M9.0).

The social demands are the primary policy that the severe nuclear accident by natural disasters should not be happened especially without damages of human health and lives. Even if probabilistic analysis is applied on the case of tsunami countermeasures, NPSs should be kept strictly safe against the quick collapse of the facilities. The author's concept is not to depend on a probabilistic risk analysis (PRA), but the deterministic design against the tsunami hazards to be considered for the NPS controls in operation near the Japanese coastal areas on the condition of the special characteristics of the severest both tsunami and seismic circumstances (seismic acceleration and displacement) in the world.

As the other solution of a possible way of designs, the author has examined the improvement of the current vertical wall of tsunami coastal embankments, which have been already constructed at the typical and important sites of the several NPSs in Japan. The coastal levees with the safe volume of the wide inside-space as for tsunami shelter, which does not collapse by the stable design of cross-sectional wide foundation with the aim to guard the human lives who are able to escape into the empty space from beaches and recreation zones that are quickly washed out by the huge waves of tsunami. Those waves more than 10m shall be generated from the Japanese ocean trenches near the 2011 earthquake off the Pacific coast of Tohoku.

The author fills broken stones inside the caisson box to fill it up, and to defend the levee to slip, or to counter the up-lift by wave forces, and turn up to fall down due to penetration of foundational mound and up-lift forces. The evacuation space of shelter role is replaced by broken stones with the aim of the design concept that the stable structure to immovable heavy bank to prevent the severe accidents of the reactors inside the NPSs.

The structural concept emphasizes that the traditional coastal levees were concrete structures, therefore results in the concrete landscape with the feeling of spiritual pressure that was unsuitable for seashore environments and also the concrete structures are inconvenient for the daily use. The proposed design of the coastal hill with vegetated park supplies environmental conditions of the turf hill, which can be used for health and recreation such as lunch spaces with the good views of open seashore lines, jogging, surfing, fishing, and even such as playing with sand/shell/water for children for adjacent residential people. This point is considerably favourite effects on local consensus for construction and the daily operation of NPSs.

CONCEPT OF THE CROSS-SECTIONAL LEVEE AND PROPER APPLICATION SITES

Internal Structure of the Levees

The defence of important nuclear power generation facilities of the rear becomes the purpose, and, therefore, it does not have to prepare for a wide area refuge place in the tsunami dike, and, in other words, as for the basic section form of the bank body, it is the box structure that is filled with broken stones which made the bank much stable. However, the author considers that it is necessary to deploy a road of the high standard in the levee body depending on a location of the nuclear power generation. On that case, the first-floor spaces of the box checkmate rubble will be needed for the road in the case of a nuclear power plant. The author prepares a highly specified road for the aim of emergent transportation for the disaster mitigation/rescue in the second floor in place of wide areas of refuge place for the people on the beach for recreation as in the case of popular sea shore areas.

Countermeasure against Underground Penetration and Ground Improvement

On the other hand, the author has designed the lift pressure from beneath the former surface of the caisson by covering mound rocks using square blocks. On the other hand, the support strength of the solidification is enough by section stirred holes which are drilled and stirred holes which penetrates the foundation soil. However, some leaks of water are presumed between gaps both routs of consolidated soil of spherical shape and from stirred holes. The consolidated wall to stop the water penetration by the stirred sheet piles is necessary for the sea-side like Figure 4. The aggregated form composed of sphere sand stirred sheet piles is the solidification by the chemical solution of infused and stirred consolidation. Please use the headers provided in this template. Include the assigned division number for the paper in the header of the first page, as well as the header of the following pages, as shown. Do not include page numbers in the header or footer. The footer should be left blank.

Local Application Problems and Measures

When a wide tsunami coastal levee of the bank-body width by this proposal does not adapt to the topography around the site of the local nuclear power generation site, it is necessary to arrange the basement of the topography. Furthermore, many seawalls having the structure of the steel-plates of direct standing wall already are built facing the sea near nuclear power generation plants. The composed constructions of these standing straight walls can be revised in the stable structure against anti tsunami that is similar to the concept of one united caisson. It will be necessary for addition to if it embeds a box and should do connected box reinforced structure in united joint steel-rods armed-structure, and composed structures of one fixed connected caisson over the both the front and the rear sides of the direct standing wall to endure to be stable against any huge wave powers of tsunami waves. The soil-covered structure of the bank has the environmental benefits for a park-shaped tsunami coastal levee suitable for the use in daily peace, if there are the enough space sites around the nuclear power plant.

Proper Application Sites of New Levees

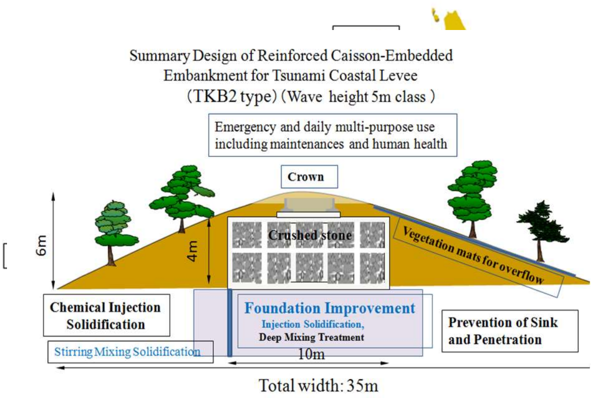

Figure **5** Stable levee for small size of tsunami inundation at calm seashore areas in the northern coastal nuclear plant sites, facing inner bays of Japanese Sea or Seto inner sea such as five or more planning nulear generation sites using MOX uranium. The Japanese energy policy requires important NPS sites such as Genkai, Tsuruga. Mihama, Takahama, Tomari, and Ikata as shown in Figure 6. The surplus purtonium is consumed as for one of the nuclear fuels on the same objectives as other proceeding countries.

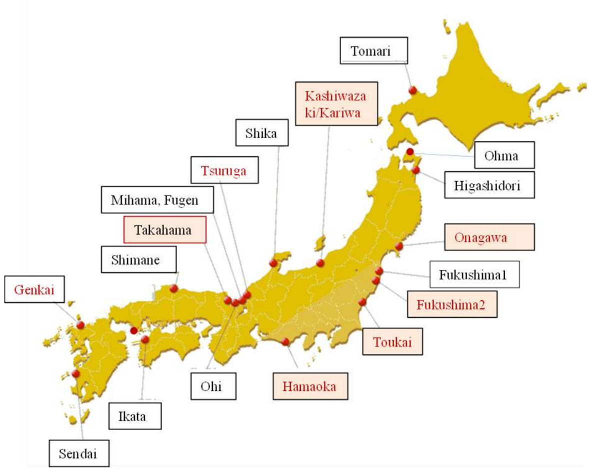

Figure 6 Distribution of Japanese NPSs (●), which are emphasizing the importance wth the red color of the NPS mark. The significant benefit were considered by generated energy, numbers of reactors, distance from megacities for demands and supply as well as special characteristics such as MOX, research organizations, and speciall function of nuclear developments. The distribution of Japanese NPSs are surrounding the coast of whole country because of the second water cooling system by the sea water.

Where are the high-risk sites of tsunami inundation?

The first question for new levees is where the highest regions of tsunami inundation in Japan, that is the most required countermeasure against the inundation for nuclear power plants. The author has chosen several corresponding sites for tsunami risky areas in the table-1. The highest risky plant will be Hamaoka NPS with 3 reactors

High risk sites with densely populated urbanized areas.

Summated population amount of the sites is the one of the severest conditions for selecting adequate NPS sites and its levees. The atmospheric dispersion of radiated matters propagates widely. If the highly populated urbanized areas are inside of the distance near about 100 km as the case of similar example near Tokyo, the NPS planners should consider that the human artificial products are not all mighty but sometimes face new unexpected design-conditions, miss-construction, and natural phenomena. Therefore, the largest water hazards may inevitably cause public infrastructures partial or concentrated damages in not precautious parts of the facilities. Consequently, in correct general-rules, NPS plants should be avoided far from highly populated urbanized areas at least until recent years.

Where are the new planning sites for nuclear facilities without design restrictions?

From the view point of "Where will be easy and simple condition without restrictions for the NPS power plants?", six plant sites should be the candidates with their considerable building spaces already prepared for plant areas. The useful sites are shown in the column No.5 of the Table-1.

The author finds severe difficulties to apply the new stable design of cross section to improve the common levees for presently existing NPS plants. The

Figure 7 One of the most important defense design for Hamaoka big NPS on the case of severest tsuami height with the geophysical reason and the fear of downstream damage to urbanized aeras of Metropolitan Tokyo as shown in Figrue 6 , that is largest demand of electric power supply using Mix Oxide (MOX) uranium reactors.

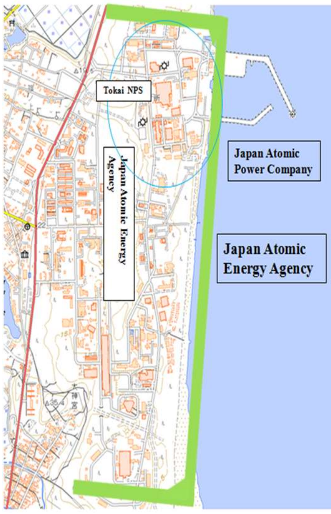

Figure 8 The Tokai NPS situates in the area of Japan Atomic Energy Agency. The facilities of Cross sectional embankments can be applied for the long length of seaside spaces with the porposes agaist the overflow incidents despites of return periods with thousands of years.

structures have not been jointed each other with steel bars across the total structure of the bank. The jointed one cross sectional structure makes stabilize the levees against the power of huge tsunami waves. The other restriction is the lack of the space for the stable width of the mound. The possible ways of improvements are as follows. One is to expand the space for levee to realize the foundation width by reclamation of the coast by shifting wharf to offshore side. However, the cost is considerable for the reconstructions in addition to the construction time more than several months or years. Consequently, to select the plant sites properly, geophysical arrangement of the existed facilities is important to apply the proposed type of the stable levee. The tentative cases of application planning could be tried to propose for most required cases of severest social and tsunami-wave height conditions of the existed NPS plants as shown in Figure-7 (Hamaoka), Figure-8 (Tokai), Figure-9 (Kashiwazaki-Kariwa) and Figure-10 (Fukushima-Futaba). The Green belts of vegetated levee can be environmental improvements, which play the role of the convenient natural park with panorama views of the seashore line in addition to emergent refuge spaces for engineers and workers against tsunami waves.

On the other hand, the author emphasizes that the simple and safest way for disaster prevention is recommended to build in the new NPS plant sites without facility restrictions quite naturally.

Multiple safety design

If the pre-existed cross-sectional structure couldn't connect each other into reinforced and armed unit body of levees, multiple defence designs are only one way of the solution for the national safety for the whole Japanese society in main severest nuclear plant sites under the highest wave-height conditions. Both the construction of the stable type of new levee in addition to pre-constructed counter measures is the answer for the fundamental design policy for multiple defences against tsunami inundation and accompanied disasters. The author proposes the sight candidates should be Hamaoka, Fukushima-Futaba, Onagawa, and could be the biggest plant sites of Kasiwazaki-Kariya near Niigata City and Tokyo, in

Figure 9 The most well known NPS in Japan with 7 reactors by likely disputed TEPCO, however they are hightly expected the re-operation for the national enegy supply to the most important energy demand from Tokyo metropolitan areas.

Figure 10 The Protection of Fukushima-2 NPS can be important for the effective recovery to reduce the contaminated soils and water at the same time of commertial electric generation by the 2 reactors, which are already closed but could be re-operate at the conveninent site near the explosion of Fukushima-Daiichi to be scrapped and safe.

addition to Takahama near Kinki economical society accompanying surrounding dense population with water resources from Biwa Lake including Osaka City.

Usual reclamation history of old inner part of breakwaters

In Japan so many ports and harbours have been reclaimed because of large ships are launched due to huge container-ships emerged in decades. The inner sea water was buried to land for warehouses and breakwaters are turned to quays with new or shifted breakwaters off-shore of the port in the deeper sea areas. The port should be renewed to the new concept of the plant system design. On the cases of the most important and plural NPS plants, the reclamation and new break water are historically normal also for new concept of multi-defence countermeasures against tsunami inundation.

THE STABILITY CONCEPT FOR THE LEVEE AGAINST WAVE FORCES

The Japanese Ministry of Land, Infrastructure, Transportation and Tourism provides a manual for the design standard applicable to the tsunami wave forces in addition to conventional forces by waves acting to the caissons outside of ports, which face to open Pacific Ocean due to the waves from typhoons and winter storms in Japan Sea. Relating factors of the caisson stability can be discussed using wave pressure, buoyancy, and up-lift force by injection of sea water under the embankment., which are shown in Figure-11 with the explanation of forces concerned. The largest embankment at Kamaishi Tsunami break water on high rock-mound are collapsed by un-expected size of tsunami wave height. The author designed the new levees not to fall down by wave moment to turn upside, coping with wide bottom of stable embankment shown in figures in my proposal. The levees must be stable against the moment by horizontal tsunami wave force by the gravity minus buoyancy of the levee and no sliding against tsunami-wave forces by friction resistance at the bottom of the caisson (Figure-12).

The new bank is covered by common natural soils with vegetation to realize the daily practical use as for coastal park because of scare probability with the long return period of un-expected size of tsunami. Design of foundation improvement is necessary against penetration of sea water at the bottom of the caissons to be stable embankment.

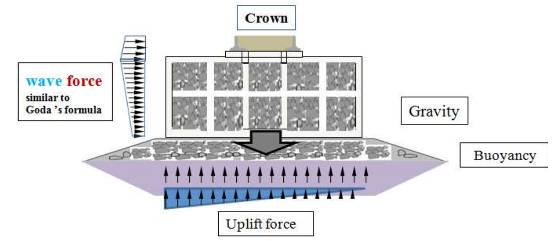

Figure 11 As for the general figure to apply with conventional wave forces, the new embankment can be drawn on the case of same assumption with the breakwaters off the seashore line. Those forces are composed of the pressure distribution by tsunami wave force, buoyancy, and up-lift pressure by injection of sea water under the embankment. The levee can be quite stable by the cross sectional wide width of heave weight and the friction between the levee bottom and the mound rocks to prevent the sink of the caissn embankment.

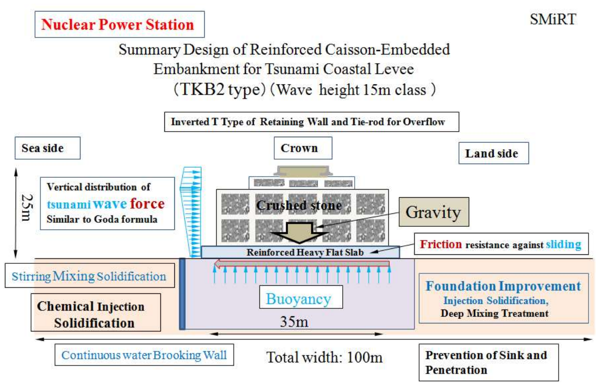

Figure 12 Design of forces relating foundation improvement. The reviee must be stable against the moment by horizontal tsunami wave force by the gravity minus buoyancy of the levee and no sliding against tsunami-wave forces by friction resistance at the bottom of the casson.

On the other hand, the author is preparing PCs and WS for the simulations of tsunami flow and wave forces using CADMS/2D and CADMAS/3D, which are developed by National Institute of Maritime, Port and Aviation Technology.

CONCLUSION

The author has proposed a stable sectional structure of stable levee against any unexpected size of tsunami without no-collapse to keep safe the nuclear power generation plants behind the bank. The proposed caisson-embedded bank enables a deterministic security-design by simplifying from the probabilistic risk evaluation methods to design the cross-section structures against the tsunami inundation.

The author has shown an original cross-section structure of stable levees against any unexpected size of tsunami without no-collapse to keep safe the nuclear power generation plants behind the embankment. The proposed caisson-embedded bank enables a deterministic-stability design by simplifying from probabilistic specifications against the tsunami inundation.

ACKNOWLEGEMENT

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REFERENCES

Daijiro, Kaneko, Restarting Normal Fukushima Daini Station or Waste Management by Applying a Collapse-Free Embankment - Aiming for Energy Supply and Accumulated or New Wastes from the Decommissioning of the Fukushima Daiichi NPS -, International Topical Workshop on Fukushima Decommissioning Research 2022, May 19-22, 2022, J-Village, Naraha, Fukushima, Japan. (In-person, 2022, October postponed)

Daijiro, Kaneko, Views for Restart of Coastal Nuclear Stations in Japan Aiming at Energy Balance and National Reduction of CO2 Exposure - Defending against Tsunami Inundation by Collapse-Free Embankments -, Ocean Science Meeting, CB15 OTP02-3, 19-22 May, 2022. (Virtual)

Daijiro, Kaneko, Continental Ocean Sciences and Impacts to Inland Human Lives and Habitats, AGU Fall Meeting 2021, Ocean Science, OS45A-02, eLightning, December 2021. (New Orleans, Virtual). https://doi.org/10.1002/essoar.10509156.1 (doi: 10.1002/essoar.10509156.1)

Daijiro, Kaneko, SY033-801430, New Designs for Coastal Levees as Stable and Safe Structures Against Un expected Sizes of Tsunami, Storm Surges, and River Flooding - Emerging Disasters by Historical M9 Earthquakes and Super Typhoons around Coastal Mega Cities for Human Habitats in Modern Era -, AGU Fall Meeting 2021, Science and Society, SY15E-0589, Poster, 13-17 December, 2021. (New Orleans, Virtual, iPoster) https://doi.org/10.1001/essoar.10509156.1

Daijiro, Kaneko and Tokuzo, Hosoyamada, Prevention of Multiple Disasters from Tsunamis, Storm Surges, and Floods using Social Models and Caisson-Embedded Banks, - A Case Study in Kanto District including Tokyo -, AGU Fall Meeting 2019, San Francisco, Public Affairs, Poster, PA33F-1145, 2019.

Daijiro, Kaneko, PA21G-1015 Tsunami Risk Evaluation of the Shonan Coast, Japan, using Geographical and Social Grid-Models, AGU Fall Meeting 2018, Public Affairs, Poster, PA21G-1015, 2018.

Daijiro, Kaneko and Tokuzo, Hosoyamada, Evaluation of Refuge Life Risk using Geographical and Social Grid-Models with Satellite-Based House Ratio and Flood Depth by Tsunami Simulation, Public Affairs, Poster, PA21D-0358, 2017.

Daijiro, Kaneko and Tokuzo, Hosoyamada, Evaluation of Refuge Life Risk using Geographical and Social Grid-Models with Satellite-Based House Ratio and Flood Depth by Tsunami Simulation, Public Affairs, Poster, PA21D-0358, 2016.

Tokuzo, Hosoyamada and Daijiro, Kaneko: Human Life Risk Evaluation and Box-Structure Reinforced Tsunami -Prevention Hill for Roads, Refuge, and Parking, Journal of Civil Engineer, B1, Vol.71、Hydraulic Engineering, Vol.59, 228, 6p, 2015. (In Japanese)