Global Environment and Ocean Engineering

Introduction to the Ocean Engineering
Concerning Environmental and Energy Issues

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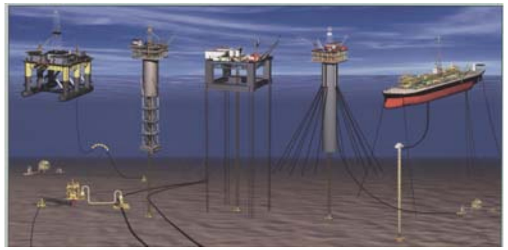
Ocean Engineering

☆Ocean Engineering

海洋石油	Offshore Oil & Gas
海底鉱物資源	Ocean Bottom Mineral
調査･探査	Survey & Exploration
生物資源	Biological Resources
海洋再生可能エネルギー	Ocean Renewable Energy
環境問題	Global Environment
海洋空間利用	Ocean Space Utilization

☆Element Technology
構造工学、流体工学、システム工学、
計算工学、水中音響学、生態学、…
Structural Engineering, Hydrodynamics, System Engineering,
Computational Engineering, Underwater Acoustics, Ecology, …

海洋石油開発 Offshore Oil & Gas



セミサブ Semisubmersible　SPAR　TLP　SPAR　船型 Ship Type

調査･探査 Survey & Exploration

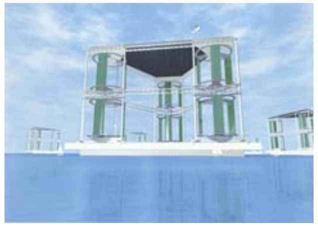
地球深部探査船
(JAMSTEC)
Ocean Drilling Ship

有人潜水船
しんかい6500(JAMSTEC)
Manned Submersible
SHINKAI 6500

AUV
うらしま(JAMSTEC)
Autonomous Underwater
Vehicle
URASHIMA

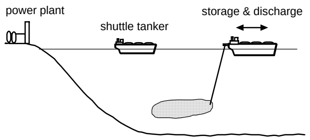
海洋再生可能エネルギー Ocean Renewable Energy

波浪、風力、海流、潮汐、温度差
Wave, Wind, Ocean Current, Tide, Thermal

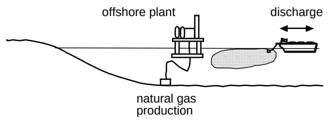


地球環境問題 Global Environment

CO2海洋隔離
CO2 Ocean Sequestration

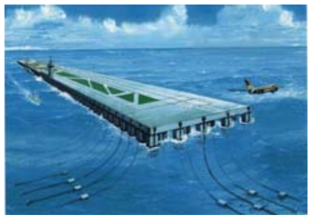


海洋肥沃化
Ocean Nourishment



海洋空間利用 Ocean Space Utilization

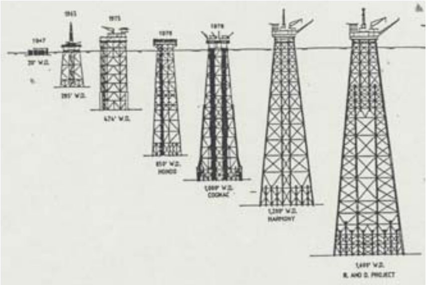
メガフロート	Megafloat
海上空港	Floating Airport
コンテナターミナル	Container Terminal
洋上備蓄基地	Floating Oil & Gas Storage
防災基地	Disaster Prevention Base
海上都市	Floating City
MOB（米国）	Mobile Offshore Base(USA)



Ocean Space Utilization using Ocean Structure

Platform Technology for Large Scale Human Activities on Ocean

海洋構造物の歴史と設計
History & Design of Offshore Structure

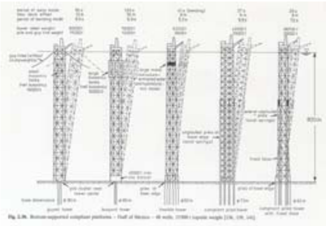


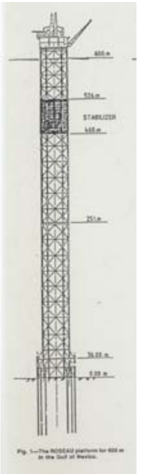
Jacket: Rigid in wave load
Max. Water Depth 410m
Bullwinkle GOM 1988

陸上から海洋へ From Land to Ocean

土木工学と造船工学の共同作業
Cooperation of Civil Engineers and Naval Architects

Compliant Tower





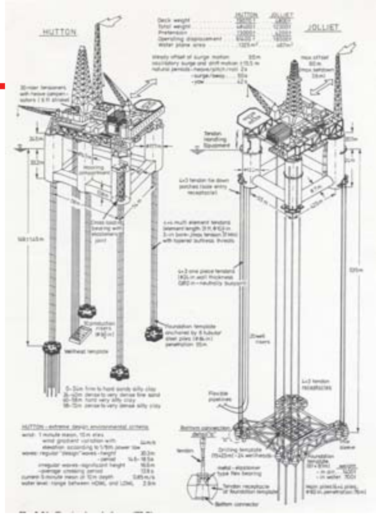
Lena ﾒｷｼｺ湾 333m(1983)
Baldpate ﾒｷｼｺ湾 500m(1998)
Petronius ﾒｷｼｺ湾 534m(1999)

TLP Tension Leg Platform

HuttonTLP 北海 水深148m (1983)
JullietTLWP ﾒｷｼｺ湾 水深537m(1989)
Auger ﾒｷｼｺ湾 水深872m(1993)
Mars ﾒｷｼｺ湾 水深894m(1996)
Rampowell ﾒｷｼｺ湾 水深981m(1997)
Ursa ﾒｷｼｺ湾 水深1219m(1998)
Marlin ﾌﾞﾗｼﾞﾙ 水深986m(1999)

固有周期
ヒーブ 4sec
サージ 100sec

Natural Period
Heave 4sec
Surge 100sec

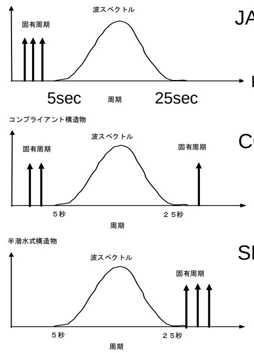


セミサブ Semi-Submersible

コラム Column
ブレース Brace
フーティング Footing
ポンツーンorロワーハル
Pontoon or Lowerhull

共振回避設計
Resonance Avoidance Design

Wave Excitation



JACKET

COMPLIANT

SEMISUBMERSIBLE

動力学系の設計
設計目標:強度と揺れ

Design of Dynamic System
Design Purpose: Strength and Motion

セミサブの変遷
History of Semi-Submersible

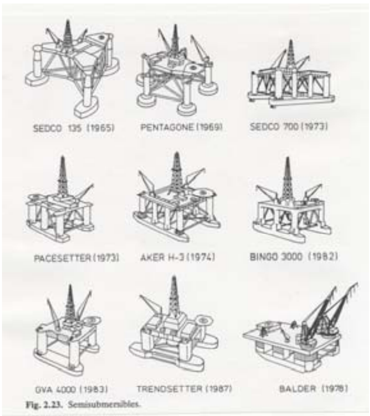


Fig. 2.23. Semisubmersibles.

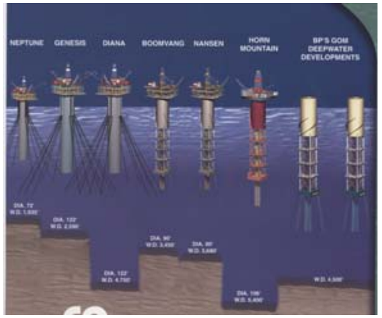
事故と大水深への挑戦
Accident and Challenge to Deepwater

海洋構造物の事故 Accidents

P—36

・アレキサンダーキーランド （1980）
Alexander Kielland
セミサブ構造様式の単純化
・オーシャンレンジャー （1982）
Ocean Ranger
・パイパーアルファ （1988）
Piper Alpha
セーフティーケース
・ P—36 （2001）

SPAR Buoy



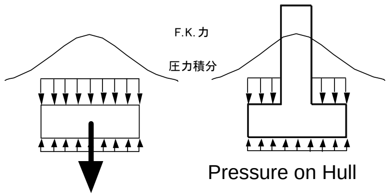
サージ固有周期 300-350sec
ピッチ固有周期 50-100sec
ヒーブ固有周期 30sec
Surge Natural Period 300-350sec
Pitch Natural Period 50-100sec
Heave natural Period 30sec

FPS
Floating Production System

FPSO
Floating Production and storage and Offloading

船と似て非なる構造物
Similar to ship but different

浮体技術 Technology of Floating Structure



海洋波：表面波
Ocean Wave: Surface Wave

波無し形状 Wave-Less Form
揺れない浮体
＝波から力を受けない浮体形状
＝動揺させた時波を作らない

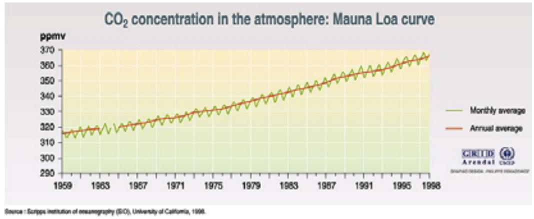
Cutting Edge Technology of Floating Structure

1) Floating Wind Turbine

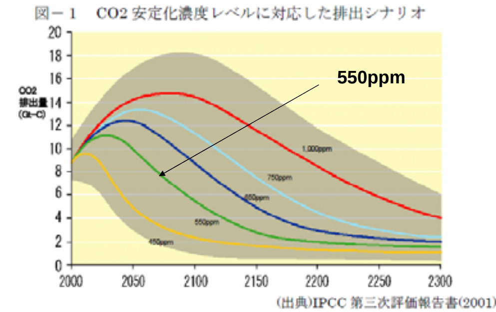
2) Very Large Floating Structure

Floating Wind Turbine

気候変動に関する政府間パネル
Intergovernmental Panel on Climate Change (IPCC）



Stabilize CO2 concentration in Atmosphere to 550ppm



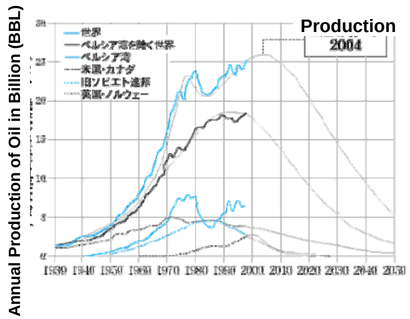
Kyoto Protocol

Reduce Emission of Green House Gas
Compared with the emission in 1990
(by 2008～2012)

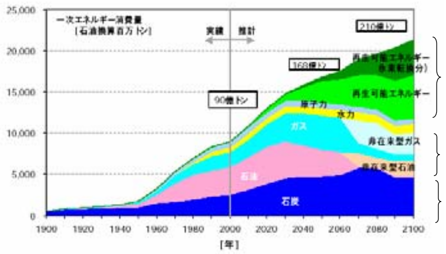
日本 Japan	-6%
EU	-8%
米国 USA	-7%
カナダ Canada	-6%
ロシア Russia	0%
total	-5.2%

Oil Peak

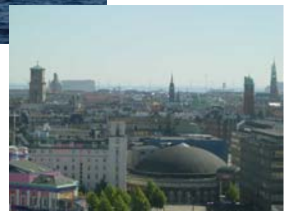
Production of Oil will start to decline soon



Long Term Prediction of Energy Consumption



Wind Turbine in Europe



Denmark
ミッドグルンデン洋上風力発電40MW

風力発電で国内電力の16%をまかなう

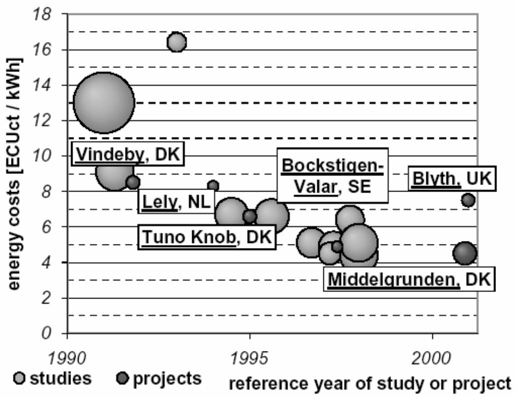


Fig. 4: Reduction in Cost (Kühn et al, 1998) (Sørensen et al 2000)

Wind Energy in Japan

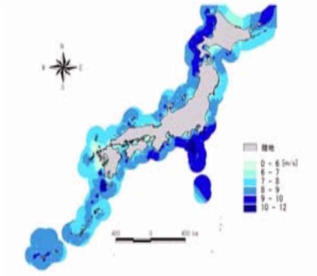
★Land

Target: 300x10⁶kW（2010, 1.4% of total electricity of Japan）

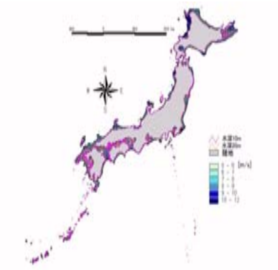
陸上の限界
資源量900万kW
建設・立地

苫前町風力発電設備

Offshore Wind Energy



Average wind speed in waters within 100km from shoreline
沿岸域100kmの年平均風速(60m高)

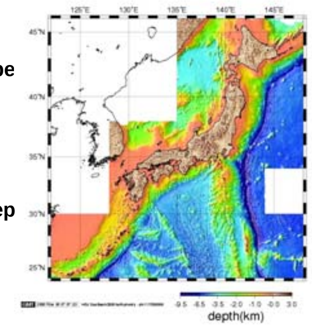


Average wind speed in waters shallower than 100m
水深100m未満の風速分布(60m高)

★Offshore
Target: 57000x10^{6}kW

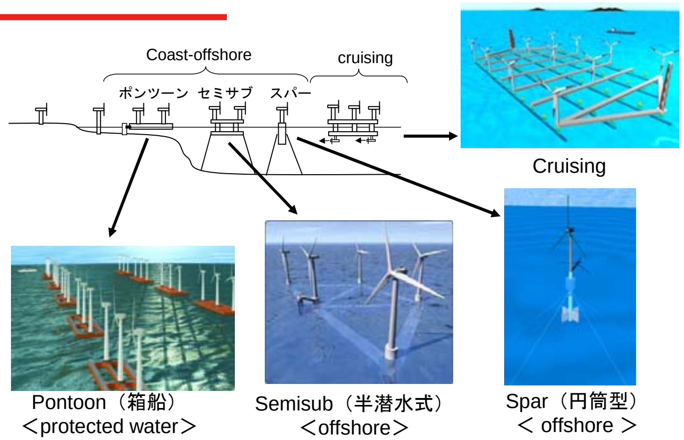
(190times larger than the numbe

★Floating Wind Turbine
Water depth becomes sharply deep



Water depth around Japan

Concept of Floating Wind Turbine



Very Large Floating Structure

1. Activities before Mega-float Project
   - Prehistory -
2. Technological Research Association of Mega-float
3. Activities after Mega-float Project
   (Ship Research Center and the Shipbuilders' Association of Japan)

History of Very Large Floating Structure in Japan

1960's	Puppet drama "Hykkori Hyouta Jima"
1973-1974	Proposal of Floating Airport for Kansai international Airport Phase 1 (semisubmersible type)
1975	Okinawa International Ocean Exhibition
1988	Kamigoto Oil Stock Pile 390m x 97m x 27.6m x 5Units
1996	Shirashima Oil Stock Pile 397m x 82m x 25.1m x 8Unit
1994	Proposal of Floating Runway for Kansai international Airport Phase 2 (pontoon type)
1995/5	Technological Research Association of Mega-float
1995-1996	Phse1 Experiment 300m x 60m
1997-	Phase 2 Experiment 1000m x 60-120m, Landing & Takeoff Experiment

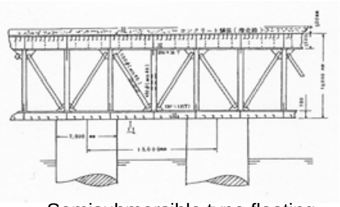
1960's Puppet drama
floating island travel all over the world

"Hyokkori HyoutannJima"

Phase 2

Phase 1

Kansai International Airport
Phase 1, 1973



Semisubmersible type floating structure

"Aquapolis"
Okinawa International Ocean Exhibition, 1975

Ushina Ferry Pier

Floating Oil Stock Pile

Kamigoto 1988 (27.7Million bbl)
Shirashima 1996 (35.2Million bbl)

National Oil Stock Pile
296.0Million bbl

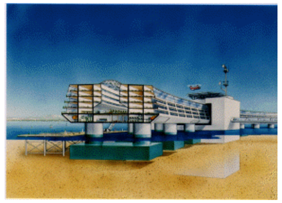
Land	7 bases
Sea	2 bases
Underground	1 base

Stock of Private Sector
296.0Million bbl

Technological Research Association of Mega-float

1993
Transport Technological Council (Ministry of Land, Infrastructure and Transportation) recommended to promote Very Large Floating Structure

1995
Technological Research Association of Mega-float



Floating City

Concepts of Mega-float

Floating Airport

Offshore Container Terminal

Sports Facility

Leisure Facility

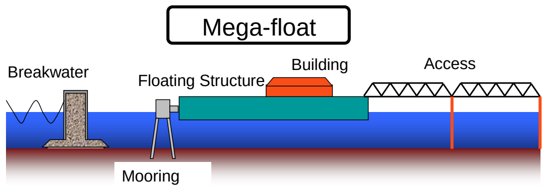
Waste Process Facility

Floating Emergency Rescue Base

Objective of the Association

1. Develop technology for Ocean Space Utilization of calm sea in large bay
   (pontoon type, cost reduction)

2. Prove and demonstrate soundness of the technology



Budget and Schedule of the Association

	Phase1 (1995-1997)	Phse2 (1998-2000)
Objective	Establish basic technology	Establish airport construction technology
Experiment	300m long model Joining of units at sea	1000m long model Joining of units at sea
Research	• Design • Fabrication and joining at sea • Operational requirement • Environmental impact	• ILS test • Landing and take off of airplane • Concept study • Legal aspect
Budget	$68.2million	$103.6million

Target Project

General Target

Ocean space utilization of calm sea in large bay

Floating airport, ocean city, emergency rescue base, leisure facilities, etc.

Focused Target

Tokyo Metropolitan Third Airport

New Runway of Haneda International Airport

Floating Airport

Shortage of Air Transportation Capacity

Annual Number of Passenger

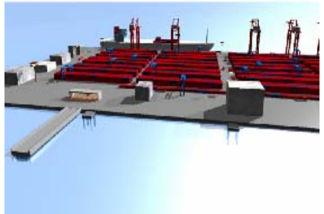
Category 1 Airport

Haneda 56.4million (Tokyo, domestic)

Narita 27.4million (Tokyo, international)

Kansai 20.5million (Kansai, international)

Itami 16.3million (Kansai, domestic)



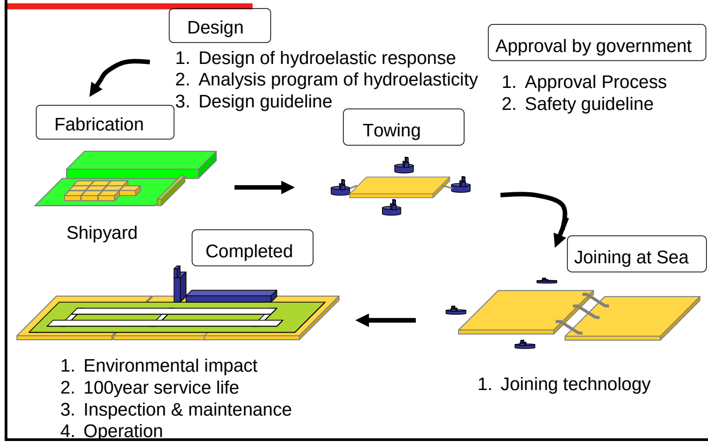
Offshore Container Terminal

Larger container ship

Installed in three major bay
Tokyo Bay
Ise Bay
Osaka Bay

Floating Emergency Rescue Base

Area of Research



Research of Mega-float

Approval Process

(1) Approval process in government.
(2) Safety guideline

Design Technology

(1) A group of analysis programs developed in various complexities and level of modeling.
(2) Functional and safety requirement studies.
(3) Design Guideline including recommendation of risk based evaluation of safety.

Construction Technology

(1) Joining technology at sea.

Operational Technology

(1) Inspection and maintenance technology for long term service.
(2) Environmental impact study
(3) Function related technology

Demonstration of soundness of technology

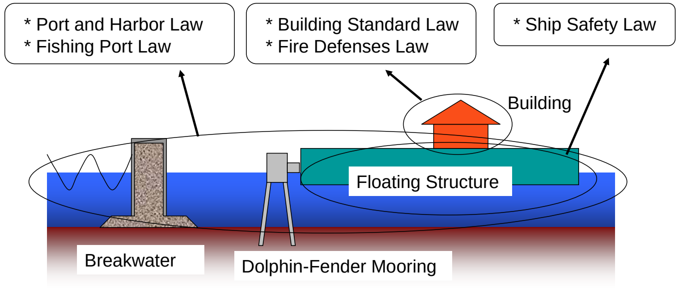
(1) On site experiments with 300m and 1000m long floater to demonstrate the soundness of technology for public and decision makers.
(2) Fabrication technology.

Others

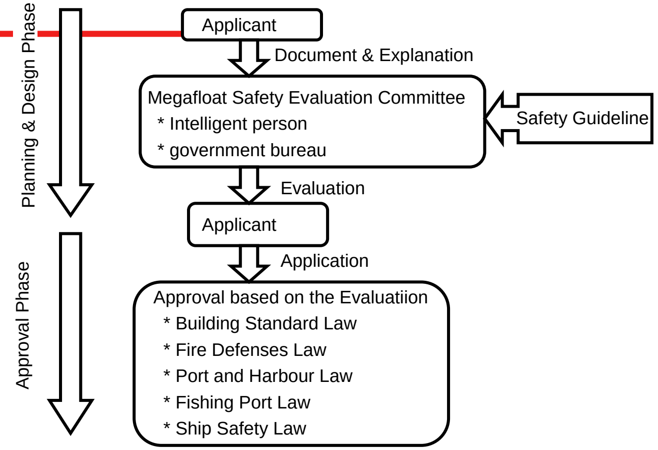
(1) Other related researches such as semi-submersible type Mega-float, Eco-float and so forth.

Safety Guideline for VLFS

Laws related to Mega-float



Approval Process in Government



Contents of Safety Guide Line for VLFS

Volume 1 General Rules
- Chapter 1-1 General
- Chapter 1-2 Fundamental concept for safety of VLFS

Volume 2 Materials
- Chapter 2-1 General

Volume 3 Design Load
- Chapter 3-1 General Rule
- Chapter 3-2 Dead Load
- Chapter 3-3 Live Load
- Chapter 3-4 Environmental Load
- Chapter 3-5 Accidental Load

Volume 4 Hull Structures
- Chapter 4-1 General Rules
- Chapter 4-2 Water-tightness and Compartments
- Chapter 4-3 Structural Strength
- Chapter 4-4 Preventive Measures against Material Deterioration

Volume 5 Station Keeping Facility
- Chapter 5-1 General
- Chapter 5-2 Configuration, Arrangement and Structural Strength of Station keeping Facility

Volume 6 Superstructure
- Chapter 6-1 General
- Chapter 6-2 Arrangement and Structure

Volume 7 Access Facility
- Chapter 7-1 General
- Chapter 7-2 Structure

Volume 8 Disaster Prevention Measures
- Chapter 8-1 General
- Chapter 8-2 Disaster Prevention Control
- Chapter 8-3 Disaster Prevention Planning

Volume 9 Quality Control for Construction Works
- Chapter 9-1 General
- Chapter 9-2 Quality Control

Volume 10 Maintenance and Inspection
- Chapter 10-1 General
- Chapter 10-2 Maintenance and Inspection

Volume 11 Overall Safety Evaluation
- Chapter 11-1 General
- Chapter 11-2 Evaluation of Safety

Development of Dynamic Response Analysis Program

A group of analysis programs were developed in various complexities and level of modeling.

1) Global hydroelastic response
2) Analysis program for structural response
   - One step method
   - Two step method

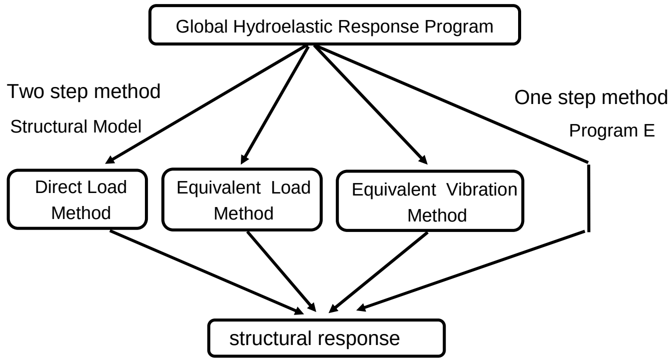
1. Global hydroelastic response

Developed Analysis Program of Global Hydroelastic Response

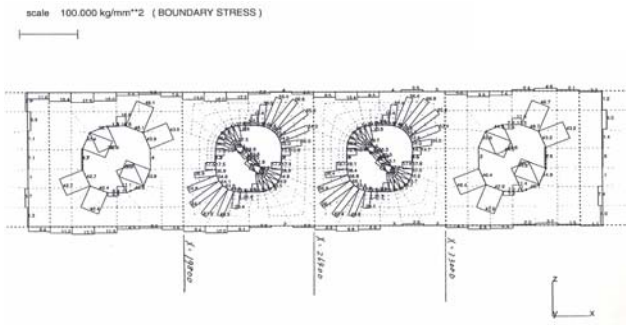
Program	A	B	C	D	E
Fluid domain	2-D DD	3-D DD	3-D DD	3-D BEM+FEM	3-D DD+FEM
Water depth	uniform	uniform	uniform	uniform	variable
Draft	uniform	uniform	uniform	uniform	variable
Structure	beam	plate	plate	FEM	FEM
Shape		rectangular	combination of rectangular	arbitrary	arbitrary
Stiffness	uniform	uniform	uniform	variable	variable
Mass	uniform	uniform	uniform	variable	variable
Beakwater			considered		considered

DD: domain decomposition

2. Structural analysis



Stress Concentration around Girder Opening



Research on Design Criteria

1. Safety
   Technical Guideline based on existing knowledge

2. Functionability
   1) Investigation of existing standard and code
      - Airport facility design standard
      - Civil aeronautics law
      - Building Standard Law
      - Standard for crane
   2) Influence of elastic response on ILS
      Series of experiments using flight simulator of airline company

Functionability criteria of runway

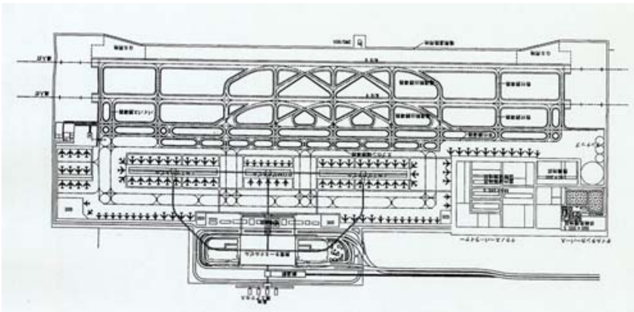
Facility	Criteria	Rule
Runway	slope longitudinal < 1.0 deg. transverse < 1.5 deg. radius of curvature > 30000m	Airport facility design standard
Taxiway	slope longitudinal < 1.5 deg. transverse < 1.5 deg. radius of curvature > 3000m	
ILS/GS	misalignment < 0.144 deg.	Civil aeronautics law
PAPI	misalignment < 0.1 deg.	

Technical Guideline for Design

Technical Guide Line of Mega-float

Volume 1 General Rules
Volume 2 Environmental Impact Assessment
Volume 3 Materials
Volume 4 Design Load
Volume 5 Hull Structures
Volume 6 Station Keeping Facility
Volume 7 Wave Control Facility
Volume 8 Disaster Prevention Measures
Volume 9 Quality Control for Construction Works
Volume 10 Maintenance and Inspection
Volume 11 Overall Safety Evaluation

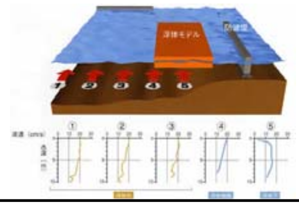
Planning of Airport Model



Environmental Impact Research

1. Flow around and below Megafloat
2. Water Quality
3. Bottom Materials
4. Oceanographic Conditions
5. Aquatic Organisms

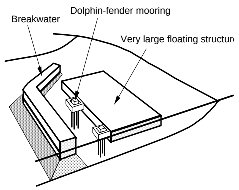
- Fish under experiment float



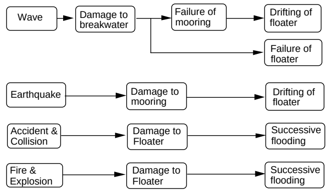
Overall Safety Evaluation

Risk based safety analysis of Mega-float system

System



Failure Scenario



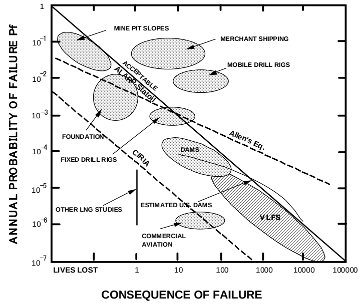
- Pontoon type floater
- Dolphin-fender mooring system
- Breakwater

Criteria

Investigation of safety of activities in Japan

Activities	FAR
Automobile	43.5
Civil Aviation	46.3
Railway (total)	4.3
Railway (passengers)	2.6
Shipping	6.3
Fire	0.20
Disease	74.9
Industries	0.64
Natural Disaster	0.016

Target Safety of Mega-float



Experiment

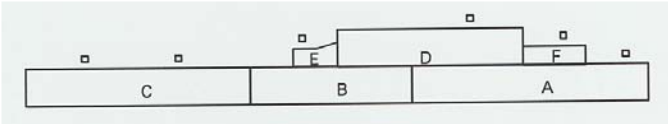
Megafloat Phase1 Experiment (1995)

9 units
100m x 20m

Megafloat Phase2 Experiment (1997)

1000m x 60-140m

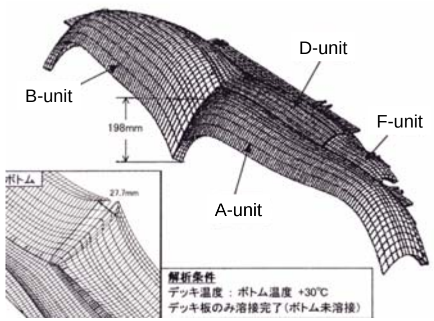
Construction of Phase 2 Model



Unit	Size (L x B x D)
A	383m x 60m x 3m
B	258m x 60m x 3m
C	359m x 60m x 3m
D	300m x 60m x 3m
E	64m x 31.3-34.5m x 3m
F	100m x 29.70m x 3m

Thermal deformation under sunlight

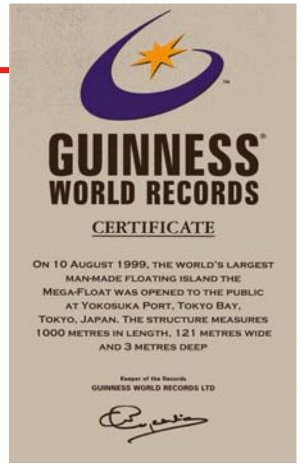
Deformation of model under sunlight was calculated for Joining at sea



Investigation of effect of elastic deformation on:

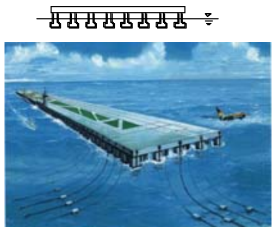
- ILS (Instrumented Landing System)
- PAPI (Precision Approach Path Indicator)

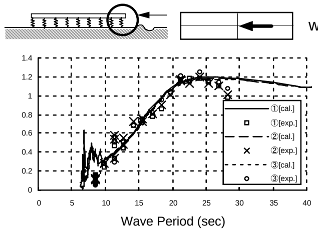
1) Test using 1000m long phase 2 model
2) Simulation using flight simulator of airline company



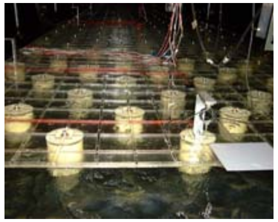
Semisubmersible Type Mega-float (related research)

1. Development of hydroelastic response analysis program VODAC
2. Verification by model test





Frequency response of deflection at bow



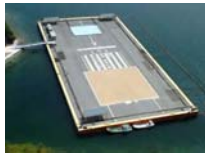
Wave tank experiment

Wind tunnel experiment

Projects after Technological Research Association of Mega-float

Megafloat Information Base
L200m x B100m x D2m

World Cup Mega-park
L200m x B100m x D2m



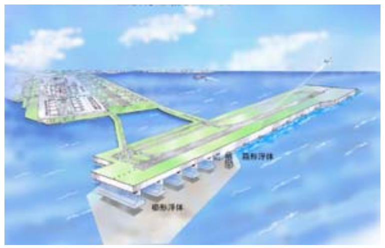
Marine Park Kumanonada
L120m x B60m x D3m

Uzushio Megafloat Nandan
L101m x B60m x D3m

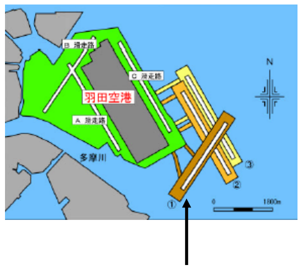
Ferry Pier
L143m x B20m x D3m

Shimizu Port Fishing Park
L143m x B20m x D3m

Haneda International Airport New Runway



Haneda International Airport



New Runway