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Infrastructure, Disaster and Climate Change in Japan

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Abstract

Since the human beings had appeared on the earth, "Infrastructure" has been supporting the society with supplying Safety, Convenience and Environment. "Infrastructure" should consist of ' Structural Measures' and 'Non-structural Measures' as well, though it has been apt to be recognized only as hard structure.

All the disasters are substantially not natural but social. Therefore, not only direct damages to hard structures but also indirect and intangible damages to soft wares or social systems should be counted in the preparation of counter measures. All available counter measures shall be planned, designed and operated in an integrated manner. Against flood disasters, "Comprehensive Flood Control Scheme" is detailed as an example of integrated basin management systems.

The pressing disasters which will be caused by climate change are not fully recognized yet and the budget for disaster prevention measures has been being reduced by the Government of Japan. .

Japanese civil engineers, however, would not give up and continue to fulfill their social responsibility. In this paper, the role of infrastructures and activities of civil engineers to mitigate, to prevent and to adapt to the pressing disasters will be stated.

Keywords: non-structural measures, soft-ware, comprehensive flood control, mitigation, adaptation

1. Infrastructure's Roles

1.1. Historical Development of Infrastructures

Infrastructures have been supporting the society of human beings for their sustainable development by supplying safety against disasters, convenience for daily life and business and sustainable natural and built environment. It is said that the man-ape had evolved to homo-sapience by establishing "society." Society had been established to ensure safety from natural hazards, predators and foreign tribes.

Three of the world civilizations, Egypt, India and China were supported by infrastructures, of course, and the great Roman Empire could not become "imperial" without its magnificent system of road, city and water supply infrastructure. The crucial role of infrastructures has been continuously increased since then. Before the industrial revolution, the role of infrastructures was to provide society safety and convenience but recent societies have added environmental expectations to infrastructures after recognizing the value of environment they had lost.

It is "civil" engineers that plan, design, construct, operate and maintain infrastructures.

1.2. Japan and Infrastructures

The present Japanese national land and society are supported by the infrastructures inherited from ancient days. They are clearly recognized as the heritages today. They have been continuously constructed during hundreds years from 7^{th} to 20^{th} Century with un emphasis on the 130 years following the Meiji Restoration in 1868 and the High Economic Growth after 2^{nd} World War. The total present asset value of infrastructures is said to be 700 T. Yen.

It is the inherited infrastructures that protected the devastated land of Japan after the loss of the War II from typhoons and earthquakes and that supported the high economic growth from '60s which realized the present prosperity of Japan.

Fig.1 "GDP, Population & Infrastructure Investment" shows that infrastructures of Japan have surely fulfilled their role of supporting the economic development.

On the other hand, it may be unfair if the infrastructures are not mentioned on their failures to protect society from natural disasters. **Fig.2** " Number of Fatalities and Missing Persons due to Natural Disasters" shows that the number are concentrated from 1945 to 1959. It means after the War, the infrastructures did not have necessary ability to protect people. The large decreased number after 1960, however, means the successful prevention of natural disasters by infrastructures. Of course, the reason of this decrease partly owes to the fact that the nature was relatively "calm" during this period of time. The big number in 1995 is the fatalities due to the Hanshin-Awaji Earthquake, which showed the failure of earthquake prevention infrastructure.

2. Disaster and Damage Defined

2.1. Causes of Disaster

Causes of disaster are classified into natural phenomena and human activity which

has the power to change the nature. The climate change and global warming are typical examples of the result of this power applied to the nature.
Therefore, the causes of disaster can be classified into three categories today.

i) Natural phenomena
ii) Natural phenomena affected by human power
iii) Human activity

What threatens the safety and security of society are disasters which are usually understood as natural and the concerned infrastructures have been mainly constructed against natural disasters. In this connection, we will focus on category i) and ii) in the following sections. Although the greatest disaster that society faces is "war" as typical human activity, infrastructure usually can not protect against it.
Natural disasters tend to be misunderstood as the disasters of "nature" which are beyond human capability. However, we, civil engineers, must fundamentally recognize that natural disasters are also social phenomena which are only triggered by natural phenomena. It will be clear when we consider that an earthquake occurred in an uninhabited area is not disastrous to us.
It can generally be said that all disasters are "social phenomena".
On the other hand, people recognize that such human induced disasters as war and terrorism are completely social phenomena. But they apt to underestimate natural phenomena sometimes trigger international conflicts. The conflicts in Middle East are closely connected with scarcity of water as Mr. HASHIMOTO, Ryutaro the former Prime-Minster of Japan and the former Chair of the United Nation Secretary General's Advisory Board on Water and Sanitation had pointed out.
In this paper, however, the author would mainly discuss water-related disasters in natural disasters and some human induced ones.

2.2. Changing Causes of Disaster

While the ability of human beings was limited, the problems arising from the second cause of disasters, ii) Natural Phenomena affected by human power, were rarely needed to be taken into account. Today, however, human activity has so much developed as it can heavily affect the nature. Since the industrial revolution in 19^{th} Century, the climate change or global warming has been continuously and seriously induced by increased emission of such greenhouse gases (GHG) as CO_2. The other big human activities were the development of cities, and cultivated lands with reclamation of forests, hills, wetlands, shores etc. We, civil engineers, must not forget that we had been supporting these human activities. The technological development of civil engineering had enabled human beings to change topography, under-ground space, ocean and shore, and eco-system of fauna and flora.

It is most ironical that the effort of human beings to seek their safety and convenience has resulted in more vulnerable society by climate change and induced disasters.

Today, we must recognize "the nature" is not natural any more but "the nature affected by human beings."

Taking into consideration these facts, disaster prevention infrastructures today must deal with the nature and at the same time the society in order to fully perform their role.

2.3. Definition and Classification of Disasters and Damages

Before discussing on the counter measures against disasters, we will systematically define infrastructure-related concepts such as disaster and damage based on the feature discussed in the sections below.

2.3.1. Natural vs. Human induced

Natural: weather and climate, earthquakes

Human induced: climate change, mal-operation of utilities and infrastructures,
error of design and construction,
terrorism and war

2.3.2. Sudden onset vs. Creeping disasters

Sudden onset: earthquakes, tsunamis, landslides, chemical spills

Medium onset: typhoons, storms, floods, storm surges

Creeping: climate change, drought, ground subsidence, air pollution,
surface and ground water pollution, diseases caused by pollution

2.3.3. Direct vs. Indirect damage

People can easily recognize the direct and structural damages because they hit the daily life and business in visible way. However, people tend to overlook the indirect and non-structural ones though they are getting more serious in recent days. At the same time, we must recognize that damages to not only residents but also commuters, tourists and foreigners in the affected area are extensively increasing due to the recent social structure and globalization.

The Draft Manual of Economic Damage Survey of Flood, The Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan (MLIT) mainly covers direct and monetary damages. It says that indirect monetary damage is difficult to be estimated and that if economic and statistical estimation of the indirect damage can be performed, it may be involved in the total damage. It says monetary loss of business stoppage, cost of emergency measures in households and offices may be counted as indirect damages. But the author considers the cost of emergency measures is to be involved in direct damage.

It means we have no way of estimating indirect damage at the moment. The author had proposed applying the "Input-Output Model" for the indirect damage analysis and a fair result had been achieved at Omonogawa R. and Toyogawa R. but the result was not involved into the present draft Manual.

We, however, know the paralysis of transport and information systems will seriously affect social systems and personal lives.

In the cases of earthquake, you may remember the Kobe port cannot have recovered the status of a hub-port in Asia after the Hansin-Awaji earthquake in 1995. The Japanese car industry had been in paralysis for months because of only one factory had stopped production of a part of engine after the Chuetsu Offshore Earthquake in 2007.

Direct damage: casualties, destruction of houses, buildings, plants, cultivated fields, loss of property, stock, agricultural product
social anxiety and disorder

Indirect damage: business standstill due to transport and information stoppage, loss of business chances, paralysis of information network and
public administration system

2.3.4. Structural vs. Nonstructural damages

Structural: destruction of structures , utilities, plants and properties

Nonstructural: casualties, standstill of business, social anxiety and deterioration of public security

2.3.5. Tangible vs. Intangible damages

Tangible: properties, structures, utilities, cost of evacuation, rescue, reconstruction, rehabilitation, casualties, standstill of business

Intangible: social anxiety, deterioration of public security,

2.3.6. Monetary vs. Non-monetary damages

Monetary: properties, structures, utilities, cost of rescue, evacuation, rehabilitation, standstill of business

Non-monetary: casualties, cultural heritages,
social anxiety and deterioration of public security

2.4. Counter-measures against disaster

With disaster as a social phenomenon, prevention and mitigation of damage are up to some extent within the human grasp. It may be said that the history of human beings is the history of expanding this "extent". In the complicated modern society, there are various types of damages as above-mentioned, therefore, the different types of counter measures should be implemented in accordance with their characteristics. Although structural counter measures are apt to have been considered as major ones, nonstructural ones should be recognized to have importance as similar as structural ones. Their importance will be easily understood when we consider the role of religion and shamanism with bringing people the mental stability and peace of mind needed during difficult times of disaster.

3. Infrastructure vs. Climate Change

3.1. Increased Disaster Risk by Climate Change

The problem of climate change and global warming is seriously declared in the Report IV of Inter-governmental Panel on Climate Change (IPCC). The report says the main cause of global warming and climate change is such greenhouse gases (GHG) as carbon dioxide (CO_2). It also says the climate changes will affect and degrade global eco-systems, fresh water resources, food production, sea-boards and wetlands, industries, and public health.

In Japan, the Research Committee on Global Warming and Adaptation, Ministry of Environment, Government of Japan reported the probable maximum rise of average temperature will be 4.7℃ at 2100.

Taking into consideration the fact that the share of GHG emission of Japanese construction industry is estimated 42.7%, their responsibility is much higher than generally understood. [1]

Among the various natural phenomena in tropical and temperate zones, climate change will seriously affect the occurrence of low pressure, the extreme value of fluctuation of precipitation and temperature. The disaster prevention infrastructures are designed, constructed and operated based on the statistics of past observed meteorological records and on their stochastic analysis. But it is seriously concerned that the "population" of the meteorological data will change in its statistic structure and the changed population will make the present "return period" shorter. For example, main Japanese rivers are designed against the flood of 100 or 200 years of return period and the drought of 10 years but the change of characteristics of the statistic population of heavy rainfall and drought will cause shorter return period. Analytical estimates by MLIT, shows that the return period of 100 years for flood will be shortened to 25 - 90 years. Such shortened return periods mean decreased safety and increased vulnerability.

MLIT as the main administrative agency of infrastructure estimates the situation after 100 years as follows. [2]

Increased maximum rainfall: Increase will be 10 to 30% and maximum of 50%. Northern Japan will be more seriously affected than southern Japan.

Increased flood peak discharge: Safety against flood will decrease. Return period of design flood will be shortened from 200 yeas to 90 - 145 years, from 100years to 25 - 90 years.

Increased landslide and debris flow: The scale and frequency will grow.

Increased sedimentation: Reduced capacity of reservoir and discharge capacity of river channel, degradation of river environment

Rising sea level and stronger typhoons: Higher tidal surges, bigger waves, coast erosion by un-stable supply of sand. Sea level rise by 0.6m brings 50% expansion of affected area and population or 879 km^2 and 5.93 million people.

Increased risk of drought: Less rainfall will bring severe and frequent drought. Less snowfall and earlier snow melt will adversely affect on water use system.

Changing environment, hydrology and sedimentation: Degradation of water quality and ecosystems

> **NB.** The author proposes that extraordinary weather will include heat and cold waves and heat island phenomena.

3.2. Increased Vulnerability of Flood

The topographical condition of Japan is very severe to people, where hilly mountain shares 90% and plain area does only 10%. The plain is located on river delta and sea-board. The major part of population, their property and social and economic activity concentrate in this narrow plain area which is prone to flood, tidal surge and tsunami. Increased flood runoff and peak discharge induced by urbanization have caused higher vulnerability of water-related disasters even if climate change was not a factor.

Fig.3 "Increase of Flood Discharge by Urbanization at the Tsurumi River, Tokyo" shows the doubled flood peak discharge by the same rainfall in the urbanized western suburbs of Tokyo. Urbanization, in general, brings concentration of population and their property and consequently increases damage potential. Moreover, climate change will bring about increased vulnerability in the urbanized area.

3.3. Infrastructure Investment

The public investment in disaster prevention infrastructure is fundamental responsibility of government whose paramount responsibility is to protect people from all kinds of disasters. **Fig.1.** "GDP, Population & Infrastructure Investment" shows secular change of the public investment for all the infrastructures including disaster prevention. It is clearly recognized that the budget was increased in line with economic growth until 1990s but Japanese government adopted the policy of cut-back on public works investment since 1998 at the rate of 3% or more annually.

The fact that no serious water or climate related disasters have occurred in Japan since 1960 demonstrates the benefit of the public investment, but we must not overlook the budget cut-back will introduce the higher vulnerability of society and increased damage potential when the population and their property accumulated in flood prone areas.

The public investment has been continuously cut back under the " Market Fundamentalism" policy but today this policy is considered the main cause of the economic crisis and the new New-Deal policy will be adopted which means bigger role of government to public investment.

In this connection, more positive action of MLIT whose main responsibility is to prevent disasters and to protect people with development of disaster prevention measures is expected.

3.4. Statement of Science Council of Japan and Joint Science Academies

Taking into consideration the importance and seriousness of climate change, the Science Council of Japan (SCJ) of Government of Japan which is the center of researchers and engineers has published a statement entitled "Adaptation to Water Related Disasters caused by Global Environment Change. " [3]

Thirteen National Science Academies including SCJ declared the statement "Joint Science Academies' Statement: Climate Change Adaptation and the Transition to a Low Carbon Society." In the statement, they say "Responding to climate change requires both mitigation and adaptation to achieve a transition to a low carbon society and our global sustainability" and "Urge governments to support research on GHG reduction technologies and climate change impacts." [4]

4. Role of Civil Engineers for Disaster Prevention

4.1. Activities against Disasters induced by Climate Change

The study and planning of counter measures against disasters induced by climate change will be performed from three stand points.

i) The fundamental research of the causes and effects of climate change. It is vital to deepen and widen the scope of research through such efforts as Report IV of IPCC.

ii) All the disasters are social phenomena. Therefore, counter measures should go beyond structural measures and advance through non-structural ones in an integrated and comprehensive manner.

iii) It is human beings that induced climate change and global warming. They are responsible to implement the counter measures to survive themselves.

4.2. Research and analysis of climate change

According to Report IV of IPCC, the situation will become so serious that even if Zero Emission of GHG is to be achieved today, the increase of global warming will not be stopped. Human beings must reduce GHG through mitigation and at the same time they must adapt to the changed climate. The adaptation is realistically and practically necessary.

As afore-mentioned, civil engineers have been working to prevent water-related disasters but at the same time, they have been involved in the projects which had caused increase of global warming. Therefore, Civil engineers are expected to assess their projects in the past and to perform their important role of realization of safety to people and society by applying all the "hard" and "soft" measures concerning "'Mitigation" and "Adaptation" based on the scientific research and analysis of climate change.

Because climate change is neither domestic nor short term phenomena but global and long term ones, the civil engineers must contribute to this issue in cooperation with foreign engineers and international organizations.

4.1. Commitment of Civil Engineers to GHG Mitigation

Taking into consideration the share of CO_2 emission of Japanese construction industry is estimated over 42.7%, the societal and scientific responsibilities of civil engineers are grave. The following action will be the commitment of civil engineers to mitigation of climate change.

4.1.1. Implementation of structural measures

i) Power production shift:

Water power, nuclear power and small scale power

ii) New energy:

Wind, solar ray and heat, tidal power, geo-thermal power and submarine methane hydrate

New energy must be assessed as output energy exceeds input one in life cycle or Energy Production Ratio (EPR) shall be larger than 1.0.

Study of environment degradation

iii) Energy efficiency:

Reformation of urban and industrial energy consumption system and introduction of energy saving transportation system

iv) Reduction of GHG:

Reduction of GHG during construction, operation and maintenance of infrastructure

Use of materials of low GHG emission

v) Carbon capture and storage:

Reforestation, use of wooden materials, carbon capture and storage in deep sea water and groundwater

vi) Effective location and exploitation:

Oil, gas and methane hydrate from the sea bottom

4.1.2. Implementation of non-structural measures

i) Comprehensive assessment

Lifecycle assessment of projects by total cost and total GHG emission

ii) Improvement in design

Structures are so designed as to use materials involving less GHG emission and emit less GHG in their lifecycle.

iii) Public procurement

Selection of construction contractor of structure by bidding cost and reduction of GHG

iv) Reduction of GHG

Improvement of traffic system and easing traffic jam, modal shift in transportation, recycling of construction materials, Reduce/Reuse/Recycle

v) Emission trading scheme of GHG

Construction industry must be involved in the trading scheme and Clean Development Mechanism (CDM).

vi) International cooperation:

Infrastructure issues must be involved in the agenda of international conferences as SCJ proposes in their Statement. [4] The Japan Society of Civil Engineers (JSCE) is, for example, negotiating the cooperation in climate change with the Asian Development Bank.

4.2. Adaptation to climate change

The climate change and global warming are inevitable even if all the GHG emission measures are fully mobilized, so civil engineers must commit themselves to adaptation as the most practical and realistic way to prevent and reduce disaster and damage triggered by climate change and global warming. "Adaptation" includes implementation of both structural and non-structural measures.

In the case of water-related disasters of floods and tidal surge, the integration of the traditional and modern technologies of structural and non-structural measures are developed as shown in **Fig.4** Comprehensive Flood Control Scheme.

4.2.1. Implementation of structural measures

i) Rising sea level and tidal surges:

Reconstruction, rehabilitation and raising the height of coast, port and river structures

ii) Increased flood discharge:

State-of-the-Art Comprehensive Flood Control Scheme integrates traditional and modern structural and non-structural measures as shown in **Fig.4** "Comprehensive Flood Control Scheme."

Traditional structures:

Dams, levees, river channels, flood detention reservoirs, drainage pumps

Modern structures:

Permeable pavement, site detention of rainfall in private premise, detention pond of multiple use for recreational park and arena, overflow-resistant super levee or high standard levee, inundation-resistant housing

iii) Land erosion control:

Improved 'Sabo" works, promotion of forestation, coastal restoration including sand replenishment or nourishing

Restoration of natural sediment flow in river channels

iv) Water use:

Construction of dams, aqua-ducts, use of recycled water

Desalination of sea water as emergency resource with brine waste treatment

Ground water exploitation with assessment of environment degradation, ground subsidence, intrusion of sea water, pollution by arsenic and toxic substances

v) Energy consumption:

Restructuring of city and transportation system for efficient energy consumption

vi) Extraordinary weather

Restructuring of city with counter measures against flush flood, drought, storm and heat island etc.

4.2.2. Implementation of non-structural measures

i) Rising of sea level and tidal surge:

Forecasting, warning, evacuation, rescue and rehabilitation

Hazard map of tidal surge

Change in land use including permanent evacuation or retreat from tidal-surge-prone areas in the very long range

ii) Increased flooding:

Regulation or restriction of land development and reclamation for residences, factories and cultivation of agriculture

Timely dissemination of forecasting and warnings

Evacuation, rescue and rehabilitation

Hazard map of flood and landslide

Integrated operation control of dams with accurate rainfall forecast

Integrated operation control of drainage pumps – Stoppage of pumps during inundation will be necessary to prevent rapture of downstream levee which will cause much bigger damages. The prior agreement of residents for the pump stoppage is necessary.

Designation of inundation-acceptable areas with prior agreement of residents

Flood insurance

iii) Land erosion

Monitoring of landslide, sediment and coastal erosion

Utilization of dam sediment

Hazard maps of landslide

iv) Water use

Improvement in water use efficiency

Integrated water use management

v) Extraordinary weather

Forecasting and warnings

Emergency aid

5. JSCE activity

Taking into consideration the roles and responsibilities of civil engineers, the Japan Society of Civil Engineers (JSCE), as the representative of all the Japanese civil engineers, eagerly committed itself to alleviating climate change and global warming since 1992, when the United Nations Environment Convention in Rio de Janeiro declared the approach of environment crisis. In 1994, the JSCE published "Action Plan for the Global Environment" and socially appealed the importance of environment and their commitment. [5]

To strengthen their commitment and emphasize their role at the Hokkaido Toyako Summit, the Specially Designated Committee for Global Warming chaired by the JSCE president was established in 2008 with three sub-committees of Global Warming Influence S.C., Mitigation S.C. and Adaptation S.C. The members of the committees are professors, researchers, in-house government engineers, consultant and contractor engineers of JSCE members.

Once established, the committee organized a seminar open to the public on the theme of "What is the Commitment of Civil Engineers against Global Warming?" in July, 2008. [6]

The three subcommittees are studying global warming focusing on the roles and responsibilities of civil engineers and they will submit conclusions and proposals in April 2009.

5.1. Global Warming Influence Subcommittee

The Global Warming Influence Subcommittee focuses on the effect of GHG and global warming. Some of its members were involved in IPCC activities and took part in "Earth Computer Project" of Ministry of Environment, Government of Japan to develop the computer simulation models and improve prediction accuracy.

Indications of the global warming crises include the expansion of tropical zones, increased meteorological fluctuation, rising of sea level, changes in seawater temperature and adverse effects on fauna and flora.

5.2. Mitigation Sub-Committee

The Mitigation Sub-Committee focuses on measures to mitigate GHG emission in consideration of big share of emission of construction industry. Cement, which is so central to construction industry, for example, emits large amount of CO_2.

Mitigation measures in design, construction, operation and maintenance, and public procurement of infrastructures including CO_2 emission trading will be studied.

5.3. Adaptation Subcommittee

The Adaptation Subcommittee studies adaptation measures, as practical and realistic ways against changes of climate zones, rise of sea level and changes in weather and precipitation.

The measures are both structural and non-structural.

6. Conclusions

Climate change is bringing about a historical crisis to human beings whose development has been supported by infrastructures and the very cause of climate change, it appears, is the human desire for a safe and convenient life. The development of infrastructures for their benefit has increased GHG emission and damage potential. The complex development of society has, in turn, complicated disasters and damages.

The role of civil engineers to support society is not so simple as the construction of structures but their scope of works must expand to cover every phase of society of the world over the years to come.

Taking into consideration the following conclusions, civil engineers will positively act to fulfill their responsibility as human beings expect to them.

Conclusions

i) All the disasters, especially, climate change, are social phenomena triggered by natural or human induced phenomena.

ii) Comprehensive analysis and research of global warming are required.

iii) Proposals for GHG mitigation are required.

iv) Proposals for adaptation to climate change are required.

v) Counter measures against disasters must be implemented in an integrated manner.

vi) Cooperation with developing countries is a "must" because climate change is a global phenomena and their people are severely affected.

vii) Civil engineers must respond to these requirement through implementation of infrastructures.

Fig.1 GDP, Population & Infrastructure Investment

Fig.2 Number of Fatalities and Missing Persons due to Natural Disasters

Fig.3　Increase of Flood Discharge by Urbanization at the Tsurumi River

Fig.4　Comprehensive Flood Control Scheme

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