ISO/TC71 Workshop in Moscow
2018/5/28

Essence of Sustainability in Concrete & Construction industries and the Latest Trend in Standards and Codes

Koji Sakai
Representative, Japan Sustainability Institute
Honorary Prof. of UBC
Guest Prof. of South East University
Emeritus Prof. of Kagawa University

Definition of "Sustainability" in ISO Guide 82 (2014)

"State of the global system, including environmental, social and economic aspects, in which the needs of the present are met without compromising the ability of future generations to meet their own needs*."

*Our common future, UN Brundtland Report, 1987

"Sustainability is the goal of sustainable development."

But, can you realize its meaning in our industry?

Definition of fib Model Code 2010

"Ability of a structure or structural element to contribute positively to the fulfilment of the present needs of humankind with respect to nature, society, economy and well-being , without compromising the ability of future generations to meet their needs in a similar manner."

Better, but still vague!

Let's clarify the essence of sustainability in our industry!

Sustainability Issues Related to Concrete and Construction Industry

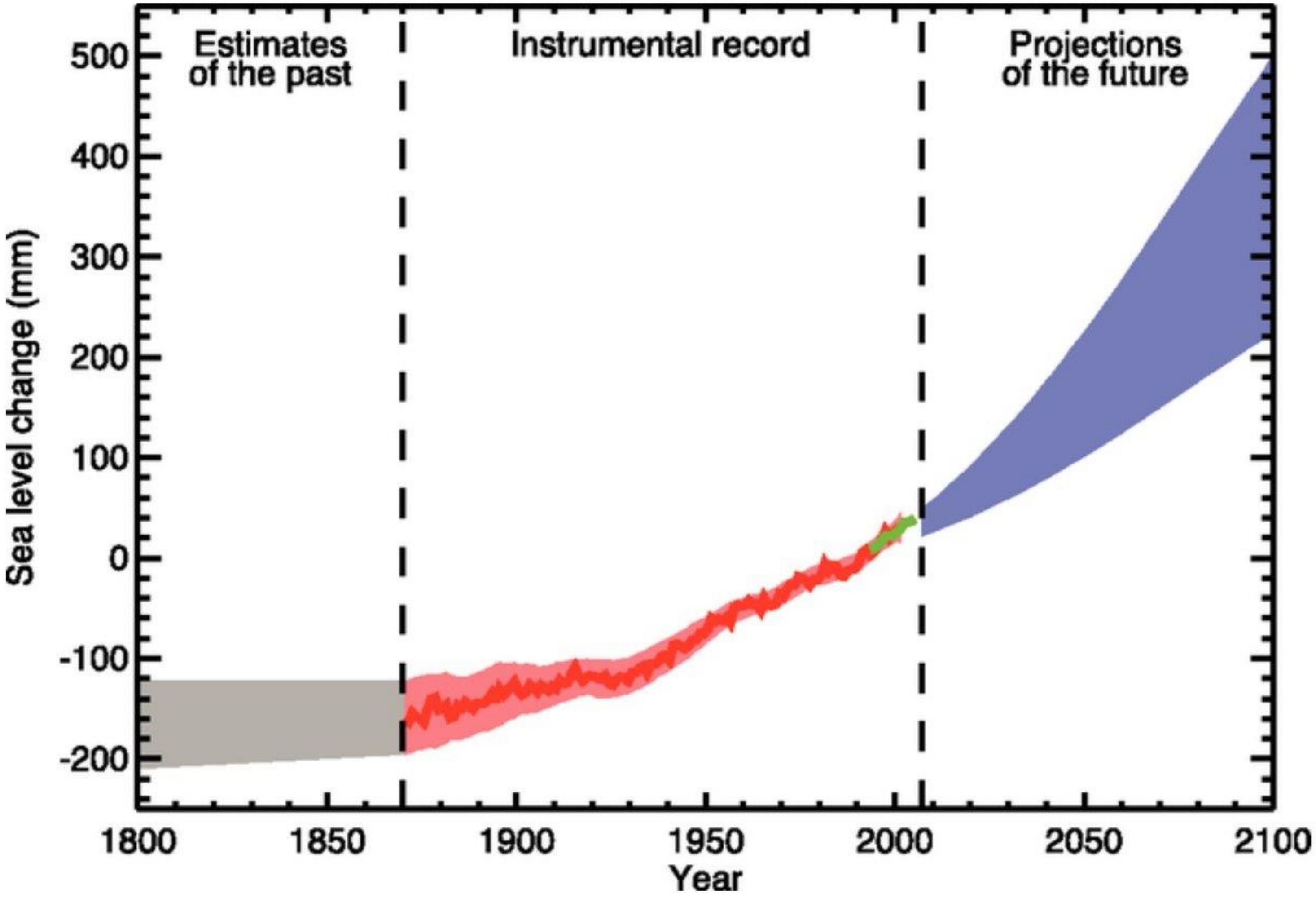
- Climate change and natural resources consumption as environmental aspects
- Cost and investment as economic aspects
- Disasters due to earthquakes, hurricanes, etc. as social aspects

Climate Change

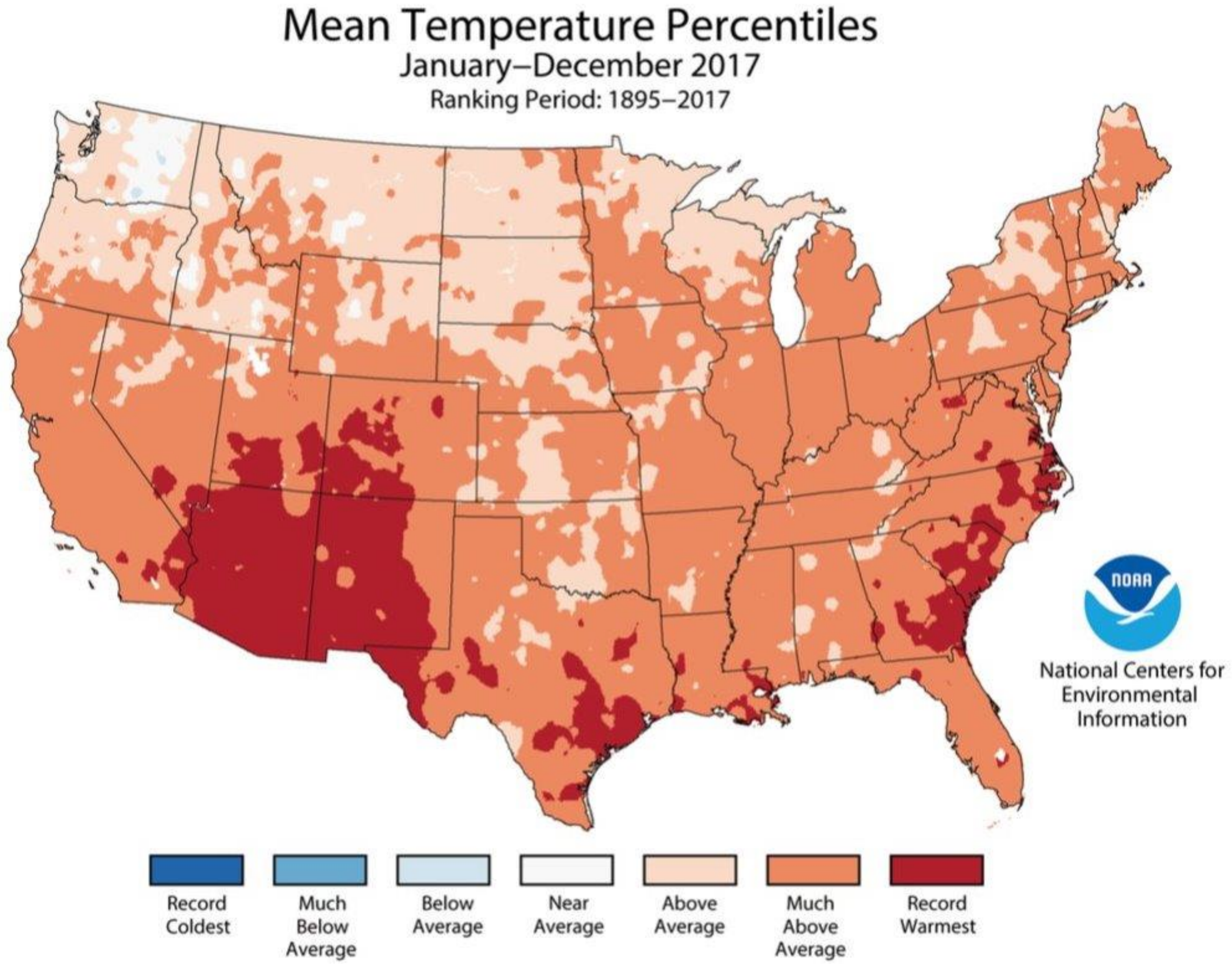
National Oceanic and Atmospheric Administration Climate Report 2017

- Greenhouse gases were the highest on record (402.9ppm).
- Global surface temperature was the highest on record (0.45-0.56℃ above the 1981-2010 average).
- Average sea surface temperature was the highest on record (0.36-0.41℃ higher than the 1981-2010 average).
- Global sea level was the highest on record (82mm higher that in 1993).
- Arctic sea ice coverage was at or near record low (the smallest in the 37-year satellite data record).

IPCC Data on Global Mean Sea Level Change
(deviation from the 1980-1999 mean)



Annual Temperature



Salmon Crisis due to High Temperature
In Okhotsk Sea

知床の高水温 2010年から
サケ北上できず 漁影響か

道内の河川をふるさととするサケの幼魚が2010年以降、海水温の上昇で知床半島沿岸からオホーツク海へと北上できない環境にあることを、サケ研究の世界的権威である帰山雅秀・北海道大学特任教授（魚類生態学）が突き止めた。道内のサケ漁が不振に陥っている大きな要因とも考えられるという。

北大・帰山特任教授が解明

帰山教授によると、道内生まれのサケは、春先に海に出た後、6月まで各地の沿岸で生息し、いったん知床沖に集結する。その後、オホーツク海を北方へ移動し、カムチャツカ半島とサハリンの間の海域に秋までとどまって成長し、11月には北西の北太平洋へ回遊。越冬して、翌年6月にはベーリング海で育つという。

帰山教授は、気象庁のデータベースなどを基に、海水温の上昇が日本系統のサケ幼魚の分布と回遊ルートに与える影響について調査した。その結果、幼魚がオホーツク海を北上することの多い7月頃の最適水温（8～12度）の水域は、00年代までは知床半島に接続していた。ところが、10年代に入ると、知床から270キロほど北側に遠ざかる傾向が強まっていた。

知床沖周辺から最適水温のエリアがなくなると、幼魚はオホーツク海を北上できなくなり、「はしごを外された状態」（帰山教授）となる。高温な沿岸周辺では、生き残っていくのが難しくなるのだという。

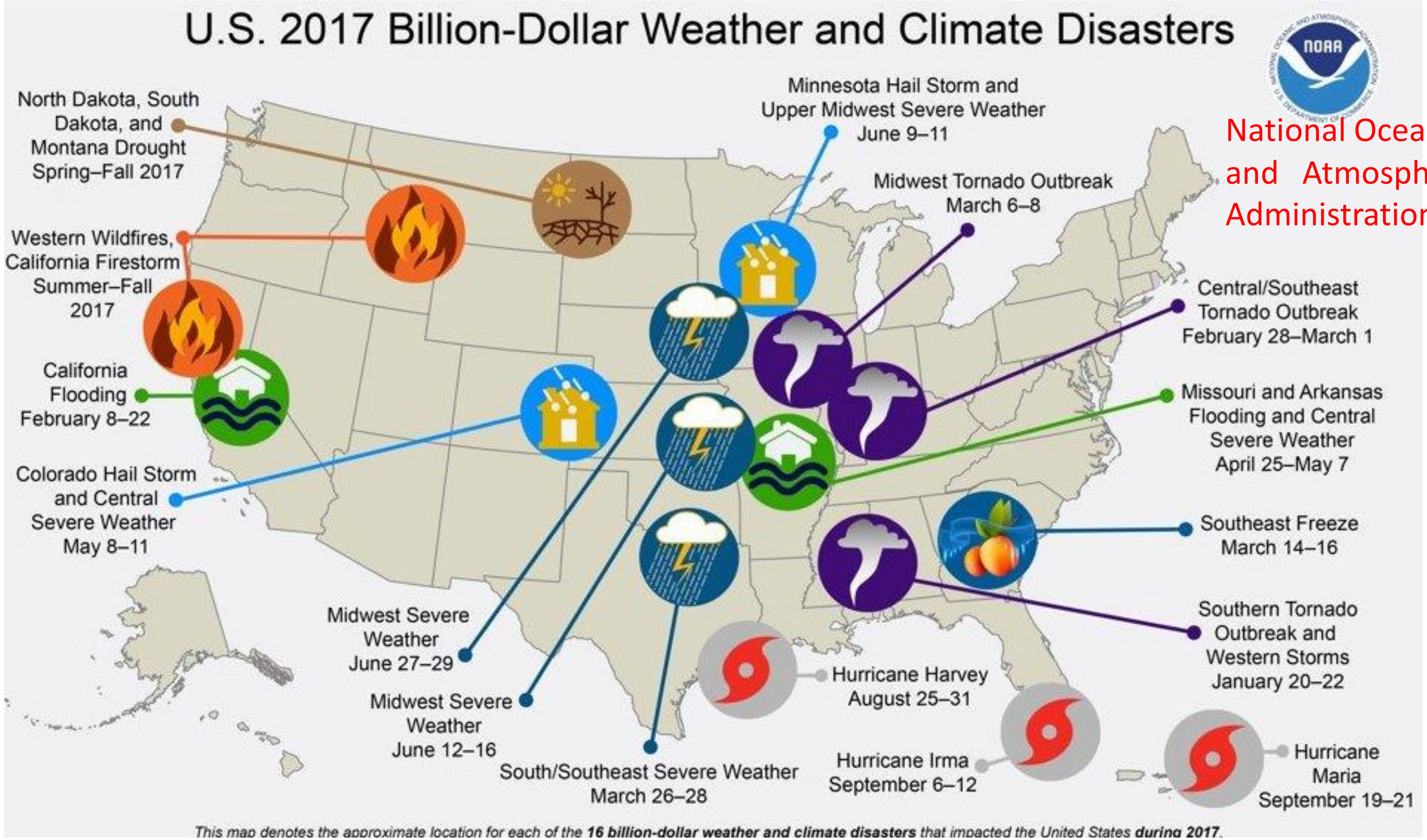
特に13年と14年はこの傾向が顕著で、その頃の幼魚が4年魚として道内に戻ってくる16、17年に記録的な不漁が続く要因になった可能性があるという。

道内のサケの漁獲量は17年、前年をさらに32%下回

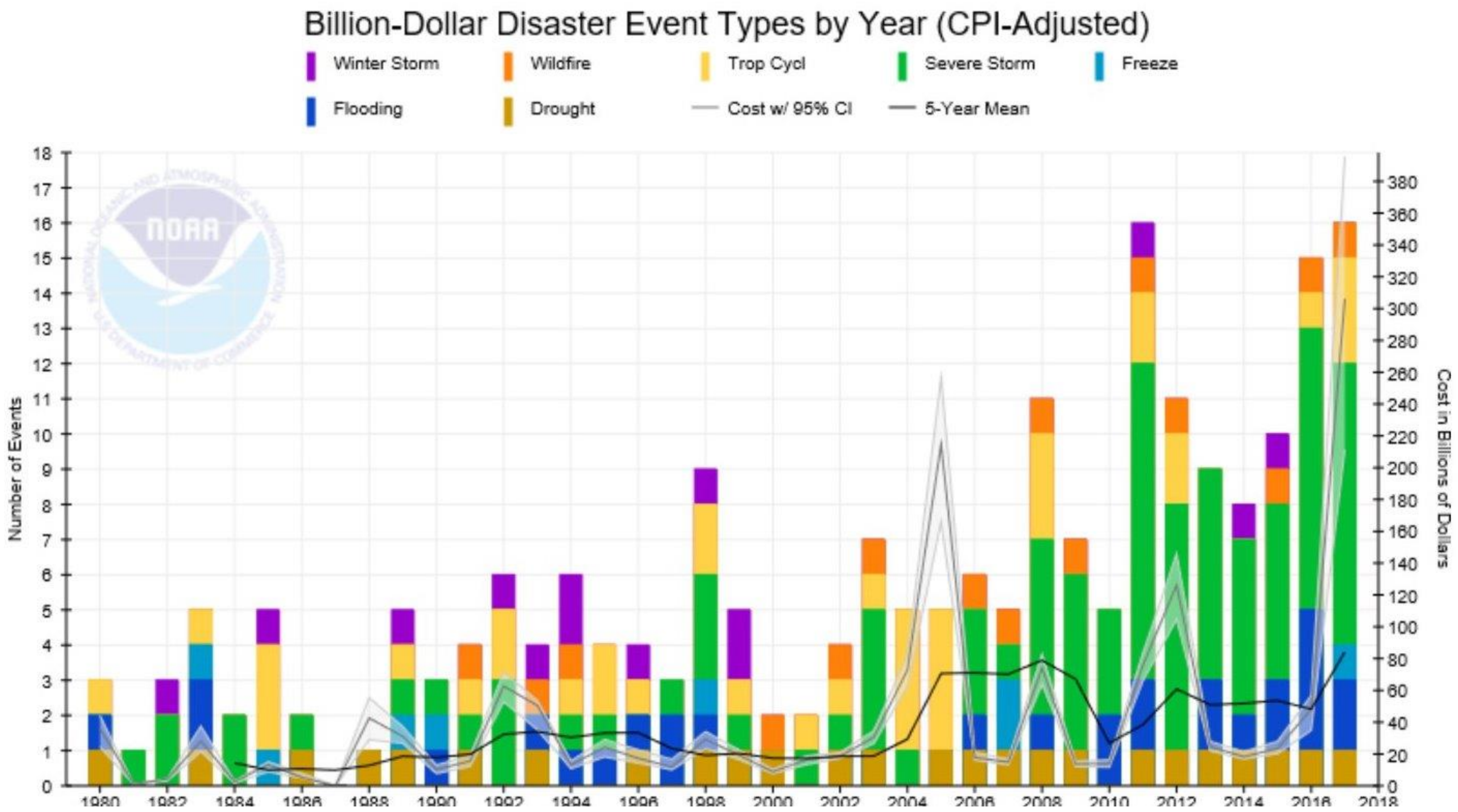
●サケ幼魚の最適水温エリア（8～12℃）

Juvenile salmons are being stocked into rivers for the growth in the northern sea, but they can not go there due to high sea temperature.

$306 Billion Losses in 2017 (U.S.)



National Oceanic and Atmospheric Administration

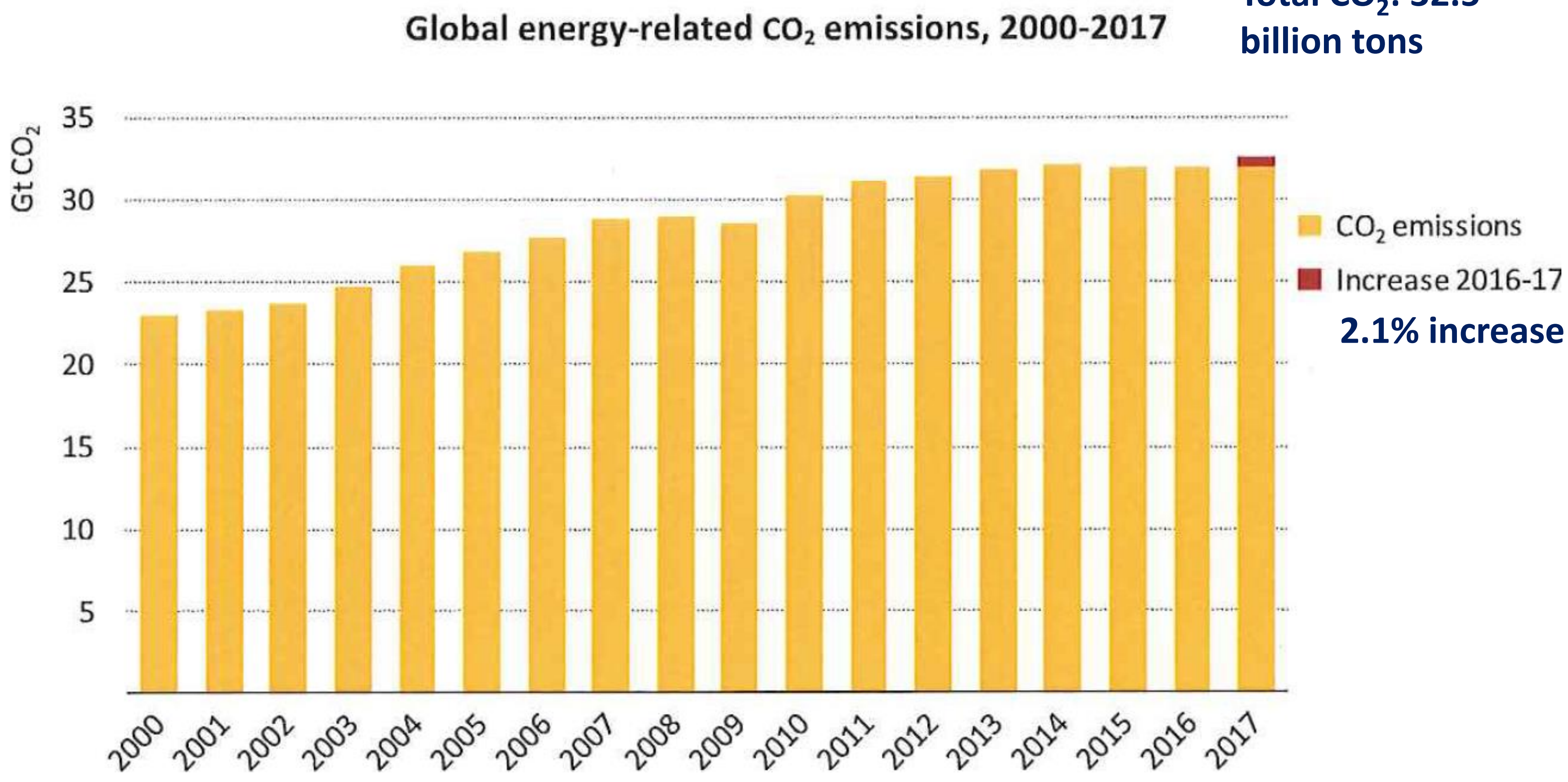


Billion-Dollar Disaster Event Types by Year (CPI-Adjusted)
Winter Storm
Wildfire
Trop Cycl
Severe Storm
Freeze
Flooding
Drought
Cost w/ 95% CI
5-Year Mean
Number of Events
Cost in Billions of Dollars
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

CO_2 Emissions from Concrete & Construction Industry

IEA Global Energy & CO_2 Status Report 2017
（March 2018)

Total CO_2: 32.5 billion tons



2.1% increase

CO_2 Emissions in Concrete & Construction Industries（estimation）

- Concrete-related industries

  Cement (Clinker): 3 billion tons

  Steel: 2 billion tons

  15.4% of 32.5 billion tons, CO_2 emitted from fossil fuel in 2017

- Concrete & construction including execution and transport

  7.04 billion tons

  22% of 32.5 billion tons

- Operation

  20% ?

Total CO_2 emissions from construction-related industry:

"22% + Operation"

Natural Resources Consumption
in Concrete & Construction Industries

Use of Natural Resources in Construction Industry (estimation)

- Steel (0.75 billion tons assumed, half of total production)
  - ironstone: 1.2 billion tons
  - coal: 0.19 billion tons
  - limestone: 0.19 billion tons
- Cement (clinker of 2.9 billon tons assumed)
  - limestone):3 billion tons
  - coal: 0.32 billion tons
- Aggregate (concrete of 25 billion tons assumed)
  - 18 billion tons
- Water (W/C=0.5 assumed) 1.8 billion tons
- Total resources consumption:

24.9 billion tons+α (execution5 billion ton?): 30 billion tons

Usage of Main Natural Resources

- Oil

  4.2 billion tons (2013)
- Coal

  3.9 billion tons (2013)
- Wood

  https://www.shinrinringyou.com/forest_world/seisan.php)

  3.5 billion m^3
- Concrete-related NR

  More than 30 billion tons
- Water

  4,000 billion tons?

Note: This fact shows that concrete is the most used substance after water.

Investors’ New Trend

NYC Climate Policy & Programs

Search

NYC's Climate Leadership

"Burning fossil fuels is the single largest contributor to human-caused climate change. Those most responsible for the damage done to our planet have denied and buried this fact despite knowing it for decades. After a decades-long pattern of deception and denial by fossil fuel companies, New York City is holding them to account. By seeking damages for the investments necessary to protect New Yorkers from the impacts of climate change, and divesting our pension funds from fossil fuel reserves, we are taking the largest action by any city to confront the growing climate crisis and adding to NYC's continued leadership on sustainability and resiliency." **-Daniel A. Zarrilli, Senior Director, Climate Policy and Programs**

Change of Business Concept

- Financial Stability Board recommended the disclosure about the effect of climate change on the business balance and assets of firms for investors' needs.
- A climate change expert was appointed as an officer of Exxon Mobil.
- Norwegian pension fund withdraws their investment from the firms which are dependent on coal
- French Insurance companies withdraw their investment from coal industry and do not sell their insurance to coal and oil sand companies.
- Government Pension Investment Fund in Japan signed the UN Principles for Responsible Investment (ESG).

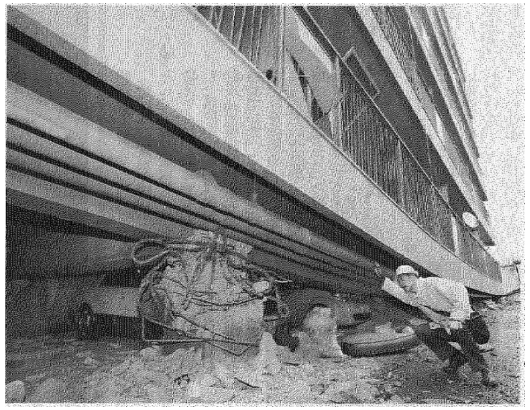
Disaster due to Earthquakes

Earthquake Disaster for Recent Two Decades in Japan

(Hanshin-Awaji, East Japan, Kumamoto)

2011

1995



2016

East Japan Great Earthquake (EJGE) in 2011

- Triple disasters
  (1) Earthquake (M9.0)
  (2) Tsunami
  (3) Radioactive pollution due to the hydrogen explosion of Fukushima nuclear power plant

What Happened in EJGE?

- Social aspect
  - Loss of many lives (approximately 20,000)
  - Collapse of social system
- Economic aspect
  - Collapse of economic activities
  - Expenditure for recovery
- Environmental aspect
  - Change of natural environment
  - Generation of rubble
  - Consumption of resources for recovery
  - Radioactive contamination

Lessons from Japan Disaster

- Without robust infrastructures and houses/buildings, human society has no chance of sustainability.
- This is the <u>essence of sustainability in regional society</u>.

- To construct and maintain robust infrastructures and houses/buildings in regional society, sustainability of construction industry is important.
- This is the <u>essence of sustainability in construction industry</u>.

What do we have to consider for
sustainability
as concrete & construction industries?

Example of Three Aspects in Sustainability of a Concrete Structure

- Social aspect

  Safety redundancy

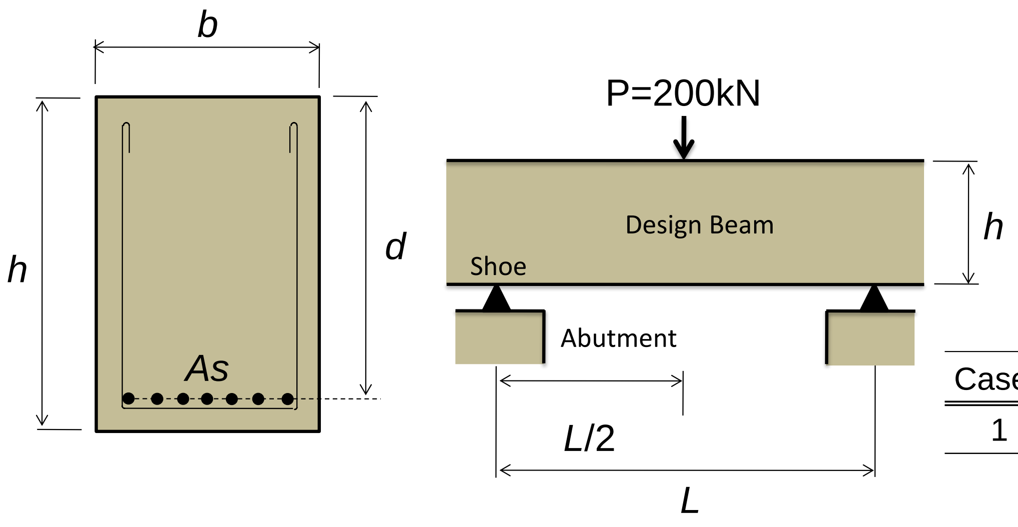
- Economic aspect

  Cost

- Environmental aspect

  CO_2

RC Beam



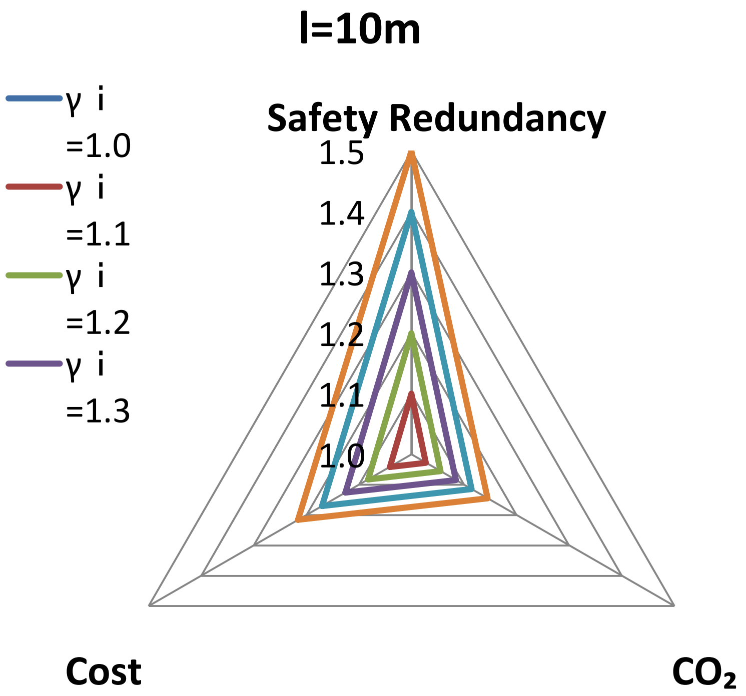
Reinforced concrete beam

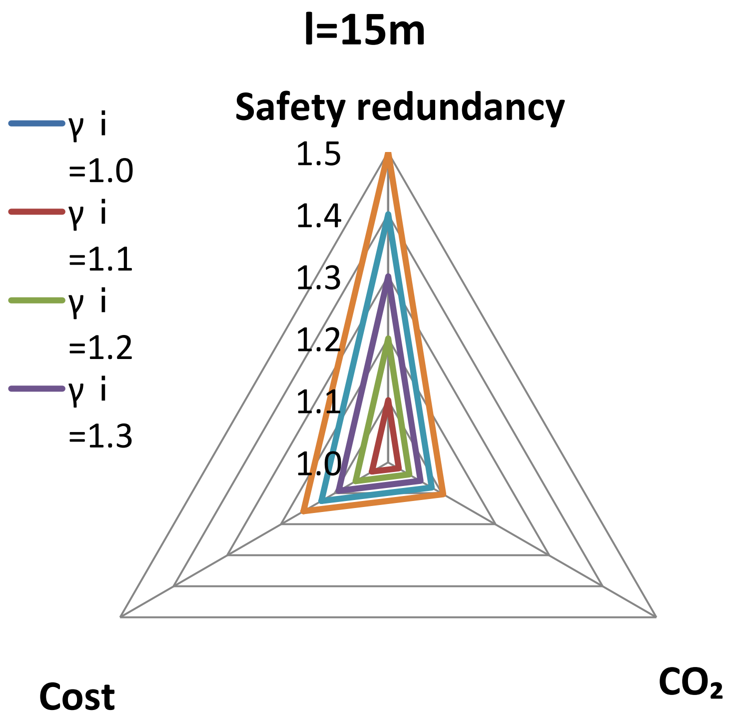
Cases	C_0(kg/m^3)	L (m)	d (m)	b (m)	h (m)
1	0	10	0.56	0.45	0.6

Fc =30N/mm^2
fs=345N/mm^2
W/C=0.48
Price of RMC=13,300Yen/m^3
Price of steel=65Yen/kg

Constituents	CO_2 (kg-CO_2/t)
Ordinary Portland cement	766.6
Portland blast-furnace slag cement (Type B)	458.7
Coarse aggregate	2.9
Fine aggregate	3.7
Chemical admixture	123
Electric furnace steel	767.4

Sustainability Evaluation





Increase of Safety Red.: 10%~50% ⇨

- Cost increase: 3.0%~28.2%
- CO_2 increase: 2.0%~19.8%

New Design System

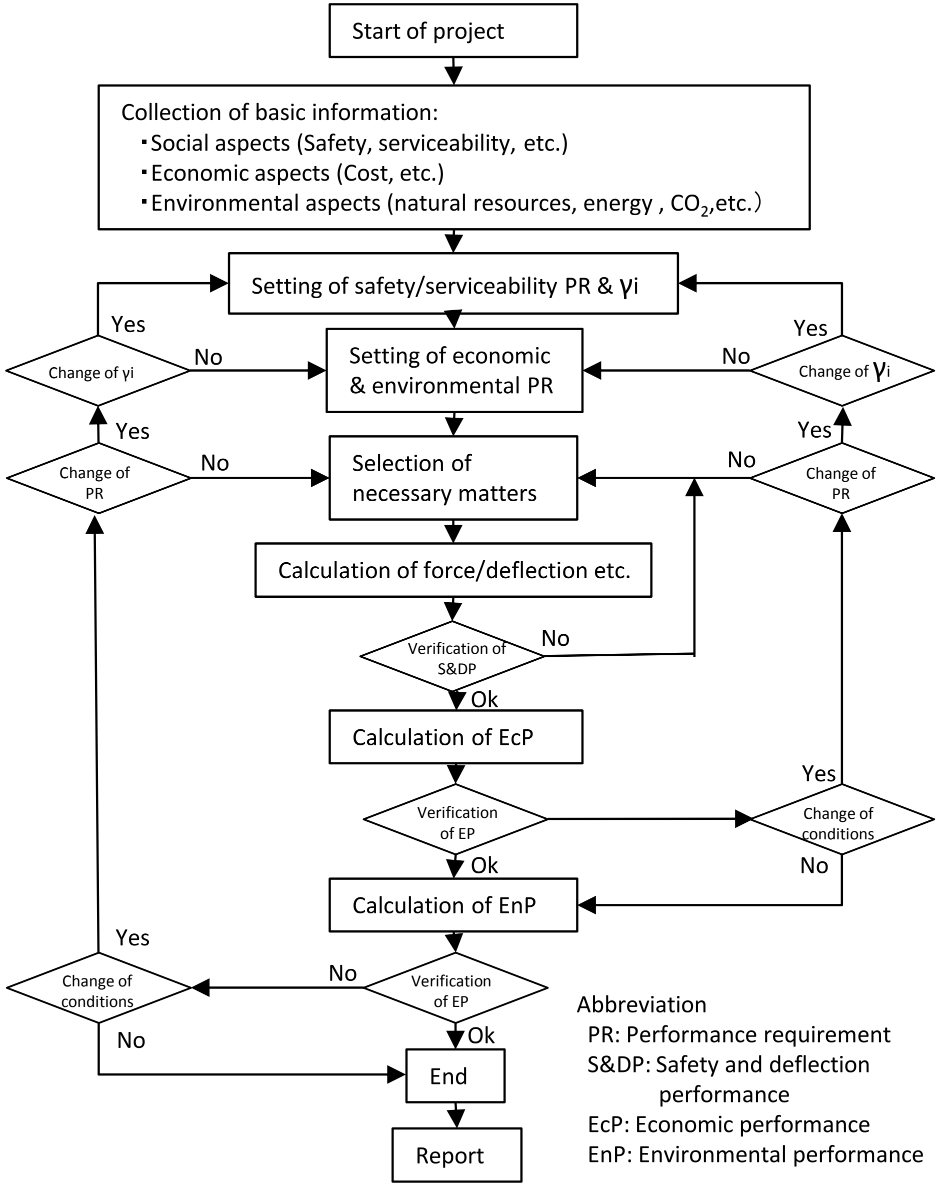
- Social, economic and environmental aspects should be appropriately considered.

  "Sustainability evaluation"

- Performance-based design system should be incorporated.

  "Sustainability design"

Framework of Sustainability Design



Verification:

$\gamma_i S_d \le R_d$

$\gamma_i \delta_d \le \delta_a$

γ_i : Sustainability factor

Abbreviation
- PR: Performance requirement
- S&DP: Safety and deflection performance
- EcP: Economic performance
- EnP: Environmental performance

System Infrastructures to Support Sustainability Design (ISO 13315)

Part 1: General principles

Part 2: System boundary and inventory data

Part 3: Production of constituents and concrete)（Under development）

Part 4: Environmental design of concrete structures

Part 5: Execution of concrete structures（Under development）

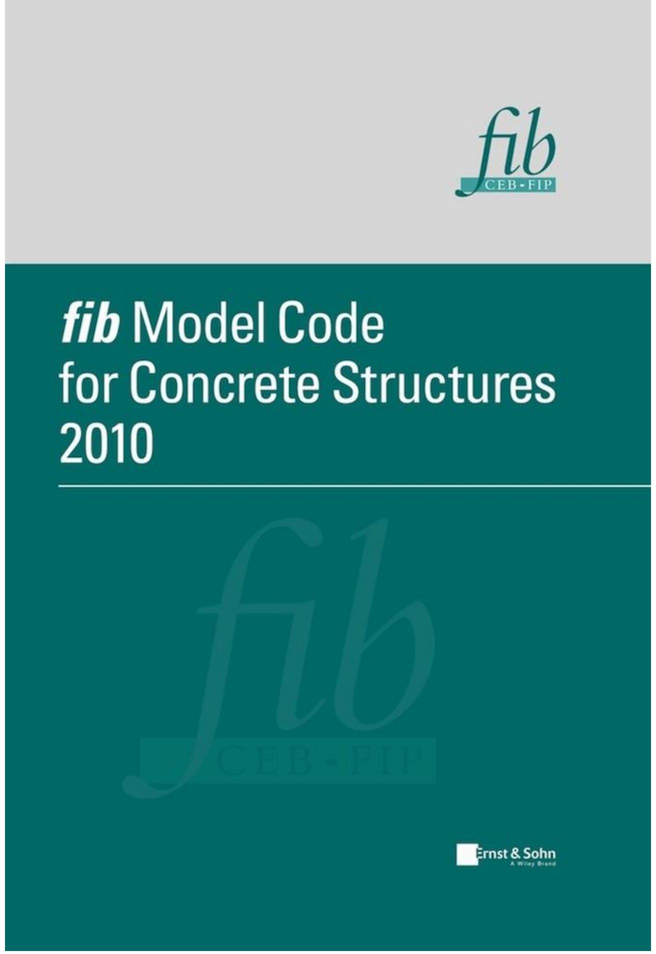
Part 6：Use of concrete structures（CD Stage）

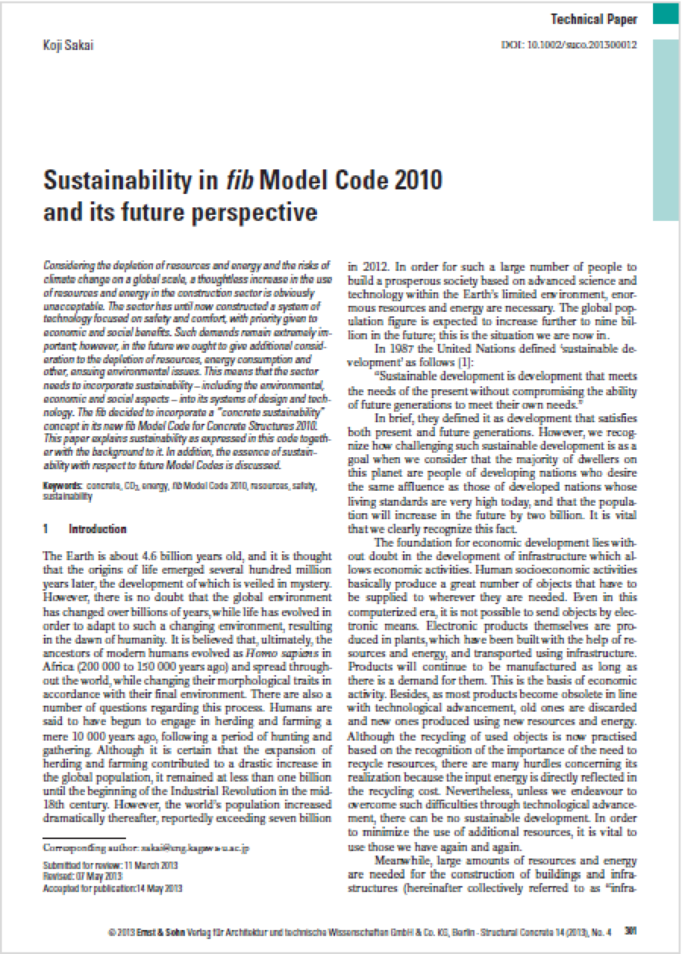
Part 7: End of life phase including recycling of concrete structures

Part 8: Label and declaration（FDIS Stage）

fib Model Code

fib Model Code 2010




Technical Paper

Koji Sakai

DOI: 10.1002/suco.201300012

Sustainability in *fib* Model Code 2010 and its future perspective

Considering the depletion of resources and energy and the risks of climate change on a global scale, a thoughtless increase in the use of resources and energy in the construction sector is obviously unacceptable. The sector has until now constructed a system of technology focused on safety and comfort, with priority given to economic and social benefits. Such demands remain extremely important; however, in the future we ought to give additional consideration to the depletion of resources, energy consumption and other, ensuing environmental issues. This means that the sector needs to incorporate sustainability – including the environmental, economic and social aspects – into its systems of design and technology. The fib decided to incorporate a "concrete sustainability" concept in its new fib Model Code for Concrete Structures 2010. This paper explains sustainability as expressed in this code together with the background to it. In addition, the essence of sustainability with respect to future Model Codes is discussed.

Keywords: concrete, CO_2, energy, fib Model Code 2010, resources, safety, sustainability

1 Introduction

The Earth is about 4.6 billion years old, and it is thought that the origins of life emerged several hundred million years later, the development of which is veiled in mystery. However, there is no doubt that the global environment has changed over billions of years, while life has evolved in order to adapt to such a changing environment, resulting in the dawn of humanity. It is believed that, ultimately, the ancestors of modern humans evolved as *Homo sapiens* in Africa (200 000 to 150 000 years ago) and spread throughout the world, while changing their morphological traits in accordance with their final environment. There are also a number of questions regarding this process. Humans are said to have begun to engage in herding and farming a mere 10 000 years ago, following a period of hunting and gathering. Although it is certain that the expansion of herding and farming contributed to a drastic increase in the global population, it remained at less than one billion until the beginning of the Industrial Revolution in the mid-18th century. However, the world's population increased dramatically thereafter, reportedly exceeding seven billion in 2012. In order for such a large number of people to build a prosperous society based on advanced science and technology within the Earth's limited environment, enormous resources and energy are necessary. The global population figure is expected to increase further to nine billion in the future; this is the situation we are now in.

In 1987 the United Nations defined 'sustainable development' as follows [1]:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In brief, they defined it as development that satisfies both present and future generations. However, we recognize how challenging such sustainable development is as a goal when we consider that the majority of dwellers on this planet are people of developing nations who desire the same affluence as those of developed nations whose living standards are very high today, and that the population will increase in the future by two billion. It is vital that we clearly recognize this fact.

The foundation for economic development lies without doubt in the development of infrastructure which allows economic activities. Human socioeconomic activities basically produce a great number of objects that have to be supplied to wherever they are needed. Even in this computerized era, it is not possible to send objects by electronic means. Electronic products themselves are produced in plants, which have been built with the help of resources and energy, and transported using infrastructure. Products will continue to be manufactured as long as there is a demand for them. This is the basis of economic activity. Besides, as most products become obsolete in line with technological advancement, old ones are discarded and new ones produced using new resources and energy. Although the recycling of used objects is now practised based on the recognition of the importance of the need to recycle resources, there are many hurdles concerning its realization because the input energy is directly reflected in the recycling cost. Nevertheless, unless we endeavour to overcome such difficulties through technological advancement, there can be no sustainable development. In order to minimize the use of additional resources, it is vital to use those we have again and again.

Meanwhile, large amounts of resources and energy are needed for the construction of buildings and infrastructures (hereinafter collectively referred to as "infra-

Corresponding author: sakai@eng.kagawa-u.ac.jp

Submitted for review: 11 March 2013
Revised: 07 May 2013
Accepted for publication: 14 May 2013

Basic Principles in MC2010

- Performance-based design and assessment
- *Performance requirements*
    - Serviceability
    - Structural safety
    - Service life
    - Reliability
    - Sustainability
- Life cycle management

Model Code 2020

- The framework of MC2020 will be based on sustainability framework.
- Only SDS will make the application of MC to existing structures possible.

Structure of fib Model Code 2020 Based on ISO 13315 Series (by Sakai)

Comprehensive Environmental Design (Part 4)				
Partial Phase	Life Cycle Range			
	(a)	(b)	(c)	(d)
Basic design (Dimensions' determination)	●	●	●	●
Execution (Part 5)		●	●	●
Use (Part 6)			●	●
Demolition/reuse (Part 7)				●

System boundary and inventory data (Part 2)

Environmental label and declaration (Part 8)

ACI Building Code

ACI Building Code Requirements for Structural Concrete（318-14）

- Chapter 4 Structural System Requirements
  4.6 Strength/4.7 Serviceability/4.8 Durability
  4.9 Sustainability
  4.9.1 The licensed design professional shall be permitted to specify in the construction documents sustainability requirements in addition to strength serviceability, and durability requirements of this code

4.9.2 The strength, serviceability, and durability requirements of this code shall take precedence over sustainability considerations. (???)

ISO TC71

ISO/TC71/SC4's Action

- ISO/TC71/SC4, chaired by Prof. Wight, formed an ad-hoc committee in the Sapporo meeting to discuss the modification of ISO 19338 (Performance and assessment requirements for design standards on structural concrete).
- The issue is how to incorporate "sustainability" into ISO 19338.

What Should We Recognize for Our Future?

- Recognize the advancement of design methods:
  - -Allowable stress design
  - -Limit state design
  - -Performance-based design
  - -Sustainability design
- Recognize the basic structure of sustainability design:
  - -Social, economic and environmental aspects are reasonably included.
  - -"Safety" is a social aspect.

What Should We Do towards Sustainability Approach?

- Recognize that the circumstances surrounding our industry have completely changed.
- Break away from conventional old engineering towards a new direction.
- Quantify all sustainability aspects in your works.
- Realize that sustainability evaluation indicates the essence of your problems in a structural design.
- Realize that sustainability evaluation causes innovations in your technology development.

Concluding Remarks

- Our environments have drastically changed, socially, economically and environmentally, for a decade.
- Concrete & construction industries have a great responsibility for the sustainability of our society and the Earth.
- Concrete & Construction industries have to promote the transformation of values through the development of new systems based on sustainability thoughts.

“Sustainability is a Magic to Simply Deal with a Material and Structure!”