日本コンクリート工学会 Japan Concrete Institute

American Concrete Institute Always advancing

The 4th JCI & ACI Joint Seminar

Sustainable and Resilient Concrete Structures -Codes and Practices-

Sapporo Convention Center, Sapporo, Japan, July 12, 2019

Standards and Guidelines from the AIJ Reinforced Concrete Steering Committee

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RC Structures committee in AIJ

- Research Committee on Structures (Chair: H. Shiohara)
  - Managing Committee on Applied Mechanics
  - Managing Committee on Loads and Actions on Buildings
  - Managing Committee on Building Foundations
  - Managing Committee on Timber Structures
  - Managing Committee on Steel Structures
  - Managing Committee on Reinforced Concrete Structures (Chair: S. Kono)
  - Managing Committee on Prestressed Concrete Structures
  - Managing Committee on Steel-Concrete Composite Structures
  - Managing Committee on Shell & Spatial Structures
  - Managing Committee on Engineering Seismology and Structural Dynamics
  - Managing Committee on Temporary Structures
  - Managing Committee on Box-Shaped Wall Structures
  - Managing Committee on Nuclear Power Facilities

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Codes and Standards in USA

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Codes & Standards in structural design in states

Local
Code [for each state]
Standard [for USA]
Country

CBC — **It is** basically "IBC" but modified for California.

Contents of ASCE7 are used.

ASCE 7 — **Load, Structural design code** (It covers engineering fields such as loading, modeling, and deformation criteria. They are necessary for all structural system.)

ACI 318 — AISC 360/AISC 341

They are design regulations specific to RC and Steel structures.
- CBC refers the most recent version.
- Each state refers different versions.

Engineers daily refer these code.

IBC — **Model code.** It is written by the International Code Council (ICC).

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Updating regulations

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
IBC (International Building Code)	✓			✓			✓			✓ ①			✓			✓			✓
CBC (California Building Code)		✓ *1						✓ ②			✓			✓			✓		
ASCE 7 (American Society of Civil Engineers)			✓			✓				③	✓						✓		
ACI 318 (American Concrete Institute)			✓			✓		③	✓			✓			✓				
AISC 360 (American Institute of Steel Construction)						✓					✓						✓		

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Codes and Standards in Japan

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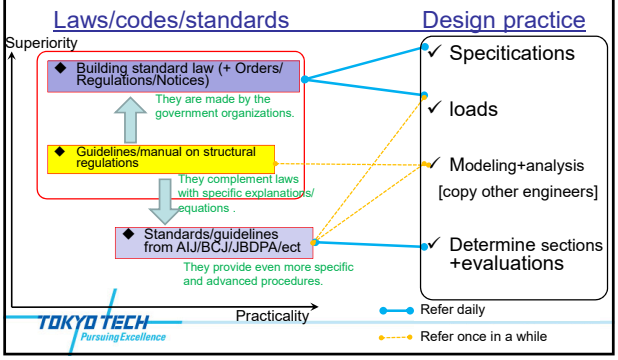
Building Codes and Standards in Japan



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Building Codes and Standards in Japan

- Building Standard Law

The Building Standard Act (建築基準法, May 24, 1950, Law No. 201) is the minimum requirement for site, equipment, structure, and use of buildings for the protection of people's lives, health and property. It was enacted after its predecessor, City Building Act (市街地建築物法 Act 37th of 1923).

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Building Codes and Standards in Japan

- Commentary on provisions in building standard law concerning structures of buildings(2015) (建築物の構造関係技術基準解説書)

  by NILIM, BRI, and others, 8,640円

It is a commentary on provisions concerning structures in the Building Standard Law and related regulations. It is the "BIBLE" in building verification(建築確認) or structural calculation verification (構造計算適合性判定).

Revised in 1981, 1986, 1988, 1991, 1994, 1997, 2001, 2007, 2015.

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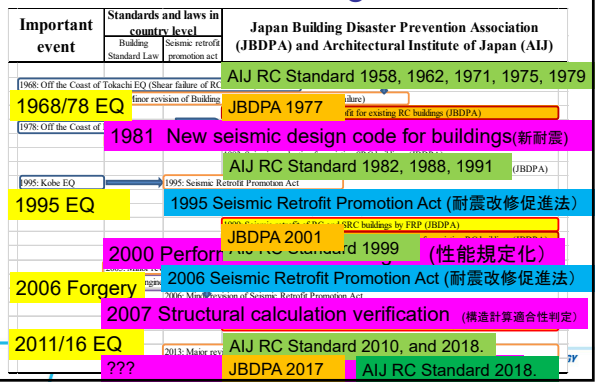
Events and design codes



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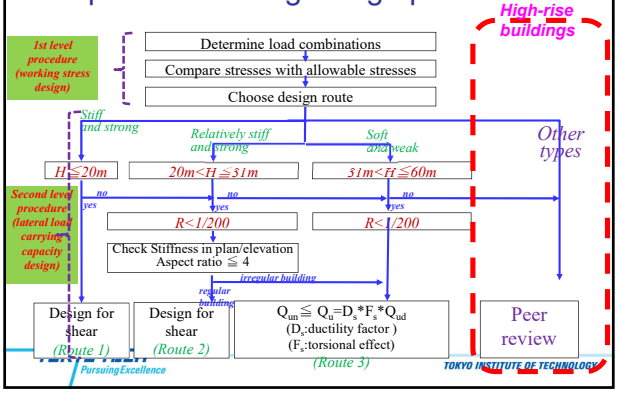
Japanese building design procedures



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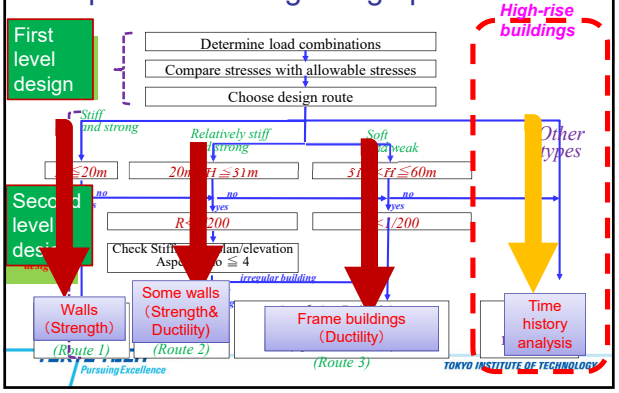
Japanese building design procedures



Design concept for safety limit states

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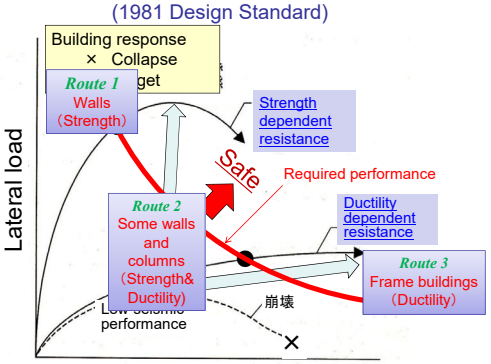
(1981 Design Standard)



Documents from AIJ

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- Reinforced Concrete Str. (general) 40
- Reinforced Concrete Str. (wall) 9
- Prestressed Concrete Str. 4
- Steel Str. (general) 25
- Steel Str. (welding) 10
- Base Isolation 3
- Loading 5
- Foundation 10

AIJ Standard for Structural Calculation of Reinforced Concrete Structures (RC規準)

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- First-level design (Working stress design)
  - The AIJ Standard for Structural Calculation of Reinforced Concrete Structures was first published in 1933.
  - The Standard was revised on many times, starting in 1947 when it was completely rewritten in accordance with the newly-established Japanese Architectural Standard No. 3001[1], which incorporated the concept of two-stage allowable stress design for long-term and short-term loadings.
  - Since then, the Standard has been revised in 1958, 1962, 1971, 1975, 1979, 1982, 1988, 1991, 1999, 2010, and 2018.
  - F'c≦60MPa, Fy<490MPa

AIJ Standard for Structural Calculation of Reinforced Concrete Structures (RC規準)

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- 1971 Revision of shear design after 1968 Tokachi-oki Earthquake
  - The current Standard still follows the fundamental philosophy set forth in the 1971 edition
- 1975 editorial changes
- 1979 revisions for footing calculations
- 1982 revisions for slab calculations
- 1988 editorial changes
- 1991 SD35 and SD40 reinforcement
- 1999 shear capacity and bond/splice/anchorage with SI unit
- 2010 concept of performance based design
- 2018 bond/splices

AIJ Standard for Lateral Load-carrying Capacity Calculation of Reinforced Concrete Structures 2016 (RC保耐規準)

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- Second-level design (Load carrying capacity)
  - It explains how to obtain the lateral load carrying capacity of buildings.
  - It assumes that engineers are able to use nonlinear push-over analysis.
  - F'c≦60MPa, Fy<490MPa

Guidelines from AIJ

- 1990 Design Guidelines for Earthquake Resistant Reinforced Concrete Buildings based on Ultimate Strength Concept (終局強度型指針)
- 1999 Design Guidelines for Earthquake Resistant Reinforced Concrete Buildings based on Inelastic Displacement Concept (靭性指針)
- 2004 Design Guidelines for Performance Evaluation of Earthquake Resistant Reinforced Concrete Buildings (性能評価指針)
- 2018 AIJ Seismic Performance Evaluation Guidelines for Reinforced Concrete Buildings Based on the Capacity Spectrum Method (等価線形化法性能評価指針)

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Performance based design concept from AIJ

- The guidelines evaluate the seismic performance of buildings by comparing their seismic response and limit capacities.
  - Seismic response is evaluated with capacity spectrum method
  - Limit capacities are evaluated at both reparability limit and safety limit states.
- 等価線形化法を用いて、想定する地震動に対する建物の応答変形を直接的に評価し、建物が保有 する限界状態と比較することにより、建物の耐震性能を評価するもの です。限界状態としては、耐損傷性と耐震安全性を取りあげています。

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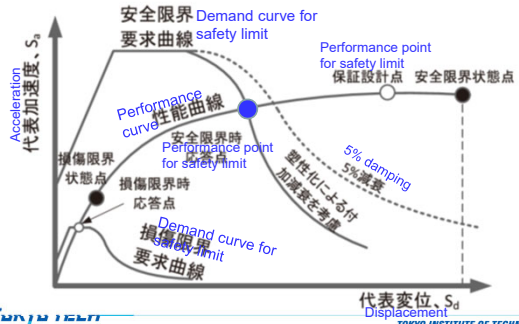
Performance based design concept from AIJ



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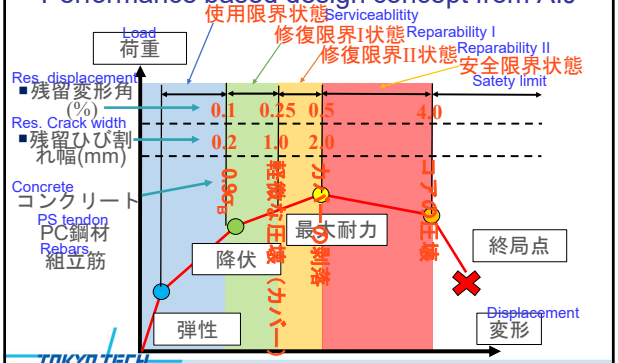
Performance based design concept from AIJ



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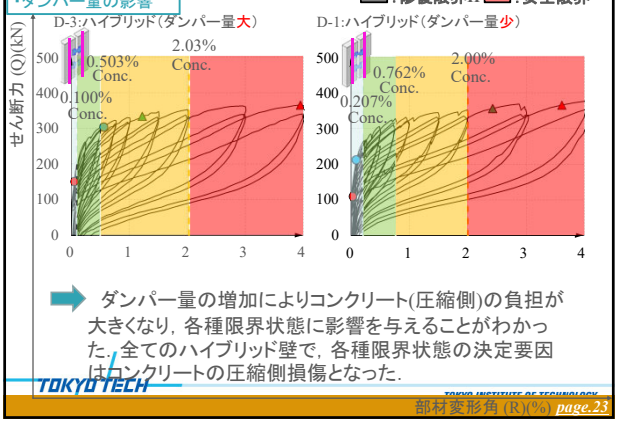
Guidelines from AIJ

Criteria of limit states for flexural members (from the 2015 AIJ PC guidelines)

Limit state	Damage state: Prestressing factor λ	Longitudinal mild reinforcement	PS tendons: with good bond	PS tendons: with deteriorated bond	concrete: General flexural members	concrete: Others	Residual drift ratio	Residual crack width
Serviceavility limit state	1~0.75	Yielding is allowed to some extent (less than yield strain)	Elastic	Elastic (less thatn 0.02% offset strain)	less thatn 0.9f'c (check strain)	less than 0.75f'c (check strain)	Neary 0 (R<0.1%)	less than 0.2mm
	0.75~0.5		less thatn 0.2% offset strain		less than (14/15λ +0.2) f'c (check strain)			
	<0.5	Elastic range (less than yield strain)			less than 2/3f'c (check strain)			
Reparability limit state I	Yielding is allowed to some extent (Strain = 1.0%)		Yielding is allowed to some extent (less than 0.2% yield strain)		minor crushing of cover is allowed (minor axial cracking due to compression)		less than 1/400 (R<0.25 %)	less than 1mm
Reparability limit state II	Buckling of longitudinal reinforcement (Visual judgement from photos)		Yielding is allowed (????? I have not thought about it yet.)	Yielding is allowed to some extent (less than 0.2% yield strain)	core concret is heathy (cover spalling)		less than 1/200 (R<0.5%)	less than 2mm
Safety limit state	Fracture of longitudinal reinforcement (from photos)		Fracture	Yielding is allowed (fracture)	crushing of core concrete (from photo)		Drift upper limit 4%	

()inside paratheses are criteria in our research group. They are not parts of the guidelines.

■ 実験結果 - 各種限界状態評価



➡ ダンパー量の増加によりコンクリート(圧縮側)の負担が大きくなり，各種限界状態に影響を与えることがわかった．全てのハイブリッド壁で，各種限界状態の決定要因はコンクリートの圧縮側損傷となった．

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Evaluation of minor/intermediate damages of RC buildings

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Kumamoto

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Lessons from 2016 Kumamoto EQ

- Safety is still the most critical issue.
- People want to use their buildings continuously after EQ's without losing any building functions.
  - Intermediate or severe damage to structural and non-structural elements cannot be accepted anymore.

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Conclusions

- Which is important document in Japan?
  - AIJ Standard is among the most valuable documents from AIJ.
  - "Yellow book" is the most valuable one for practical engineers.
- Performance based design method has been studied and codified.
  - 2004 Design Guidelines for Performance Evaluation……
  - 2018 AIJ Seismic Performance Evaluation Guidelines…….
- Performance based design may be common interest to pursuit for ACI, JCI (JSCE, AIJ), and international engineering society.

Thank you

Kamo River, Kyoto