Precast Concrete Construction in Japan

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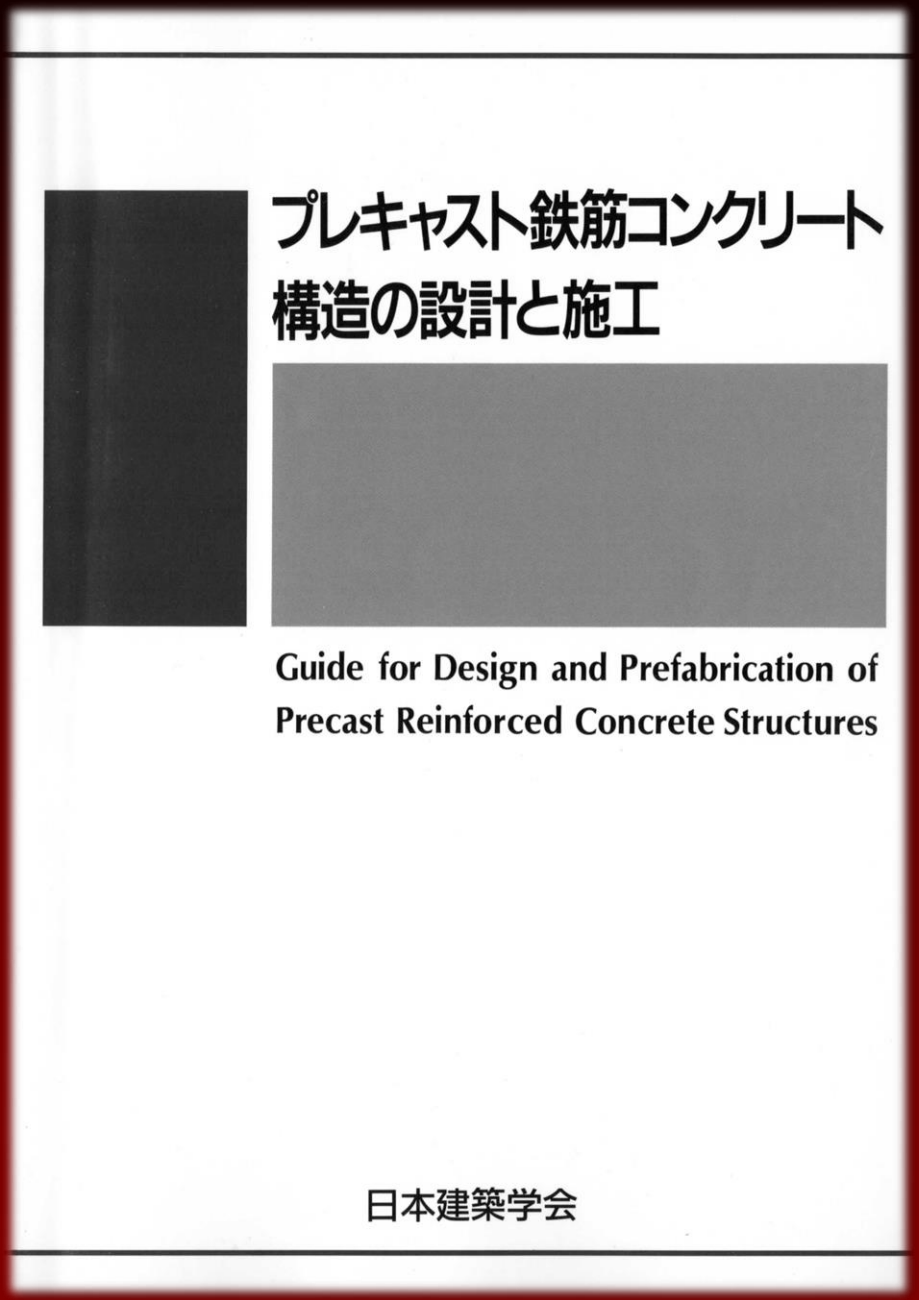
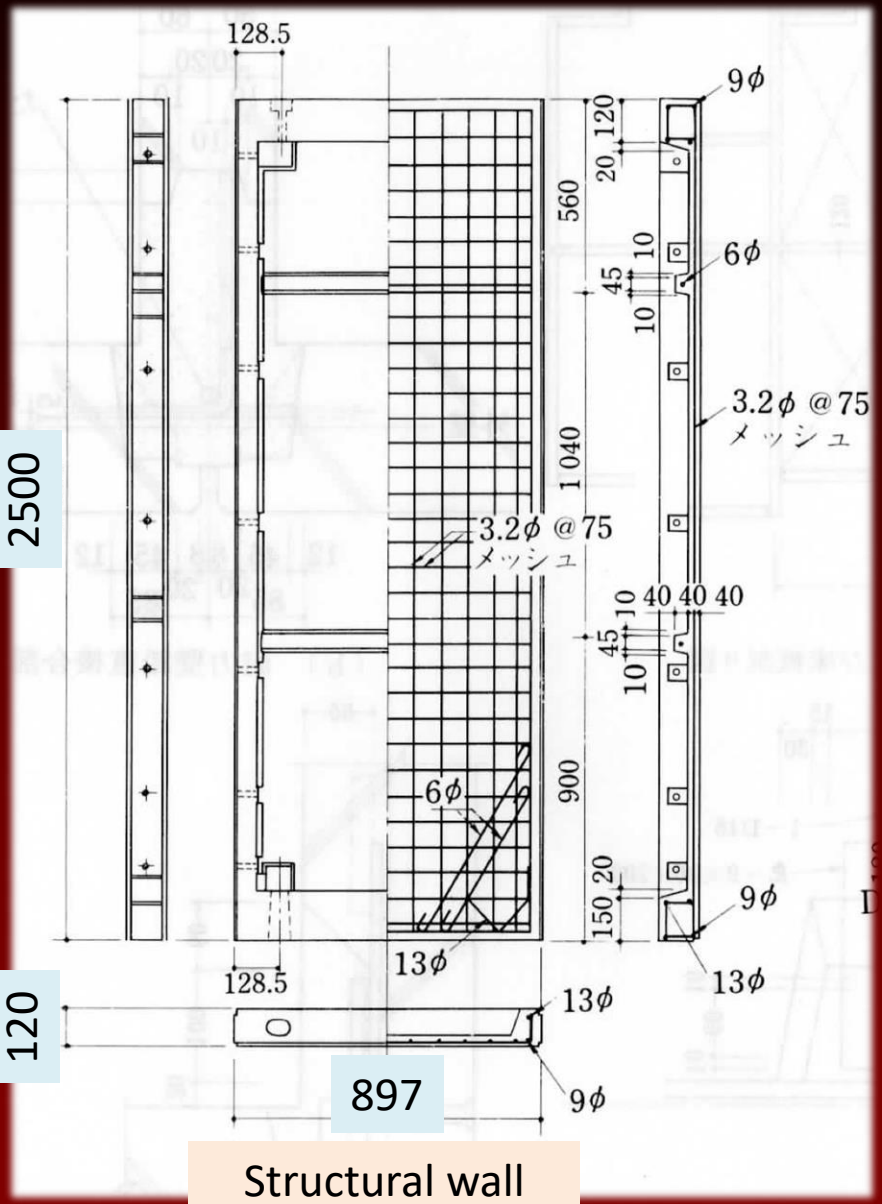
Contents

- Evolution of precast concrete (PCa) in Japan
  - thin medium-size ribbed panel for low-rise building
  - large PCa panel
  - high- and mid-rise PCa wall buildings
  - PCa moment resisting frame: rebar joints
- Current PCa housing structures in Japan
- Damage to PCa buildings due to severe earthquakes



Guide for Design and Prefabrication of Precast Reinforced Concrete Structures 1986

thin medium-size ribbed panel constructed by bolts



Structural wall

1963 Standard design
1966~72 > 10,000 units/year
150,000 units/20 years

Story: up to 2
poor heat insulation capacity
poor flexibility in plan

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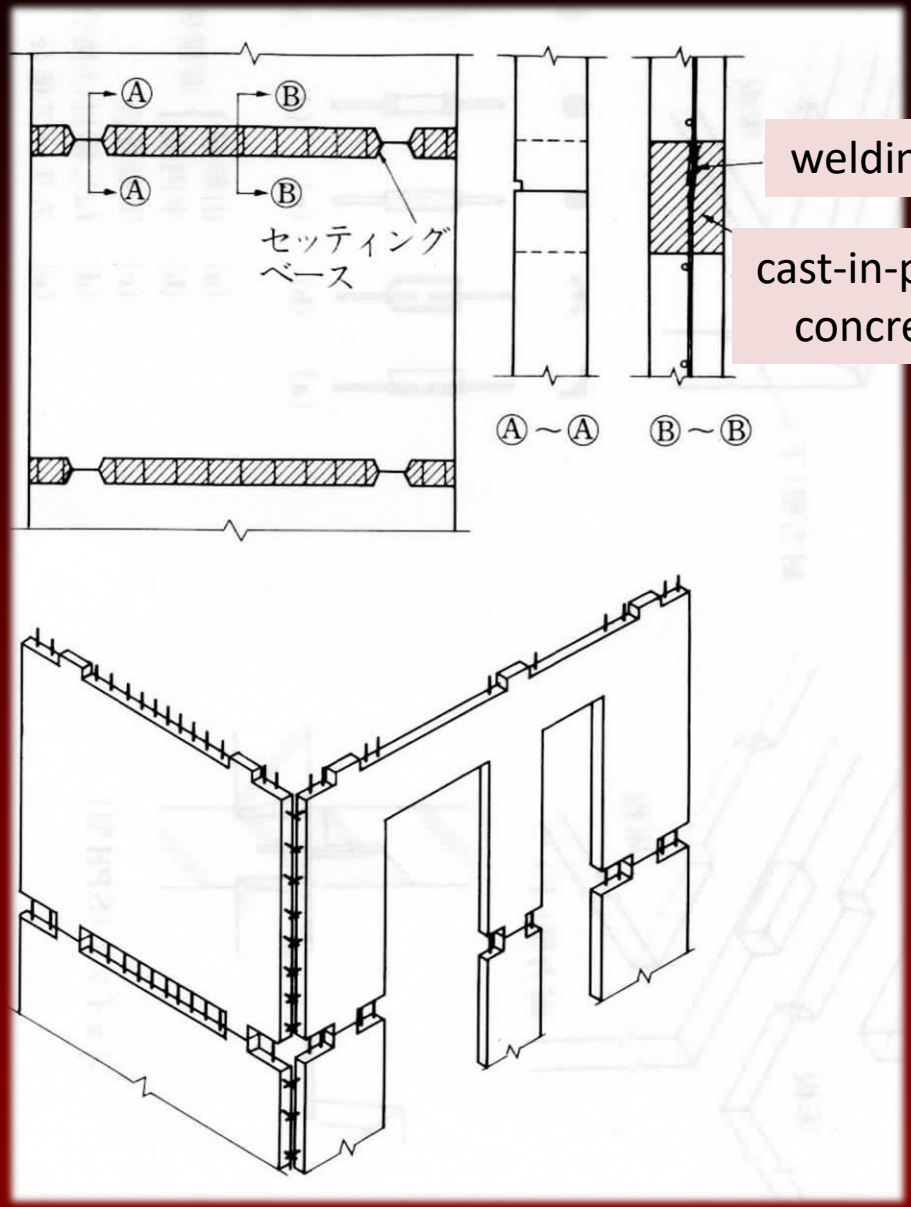
large precast concrete panel



Horizontal and vertical joints

seismic performance equivalent to cast-in-place buildings

- horizontal joint:
  welding of wall vertical rebars
- vertical joint:
  welding of wall horizontal rebars and mechanical keys with cast-in-place concrete

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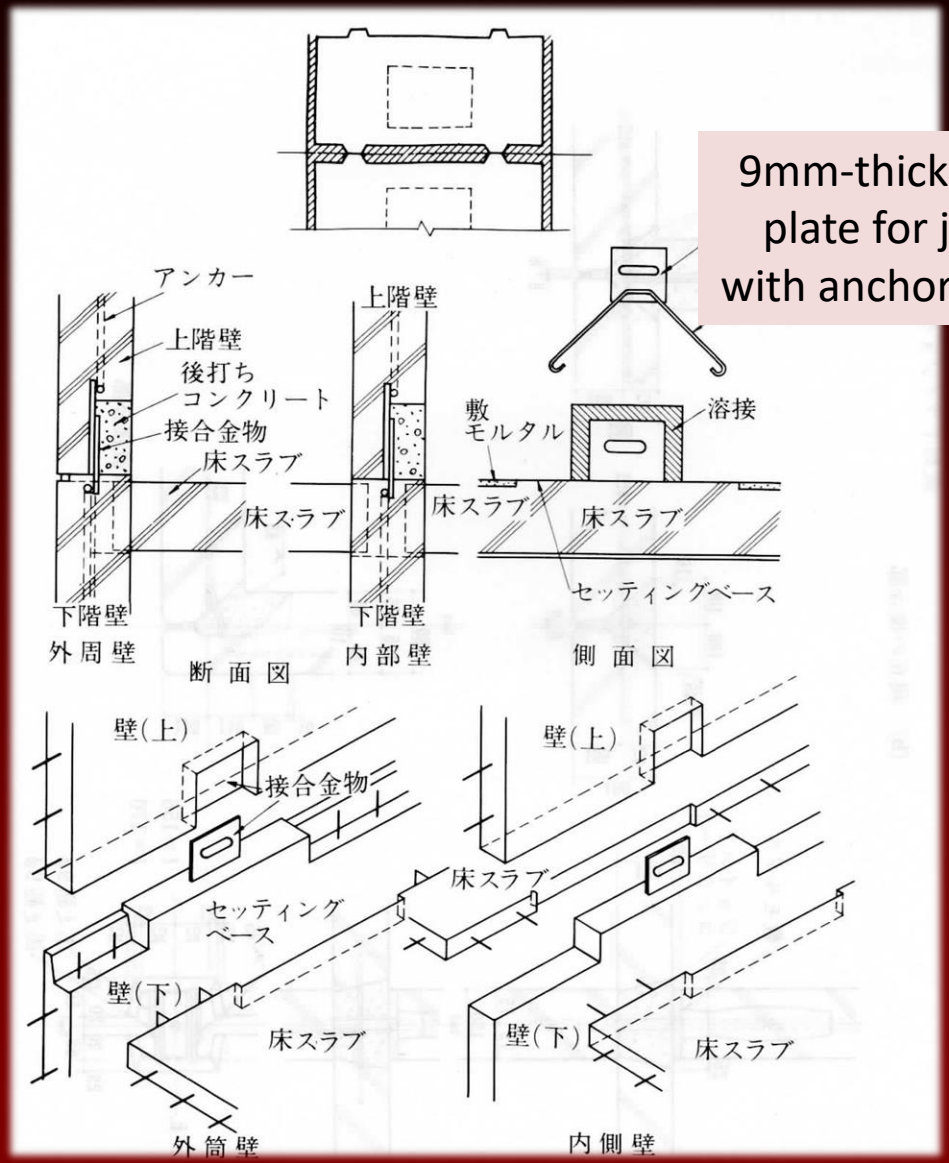
large precast concrete panel



9mm-thick steel plate for joint with anchor rebar

seismic performance equivalent to cast-in-place buildings

- wall-wall connections
  - welding of steel plates embedded in panels
  - concrete cast

Horizontal joint

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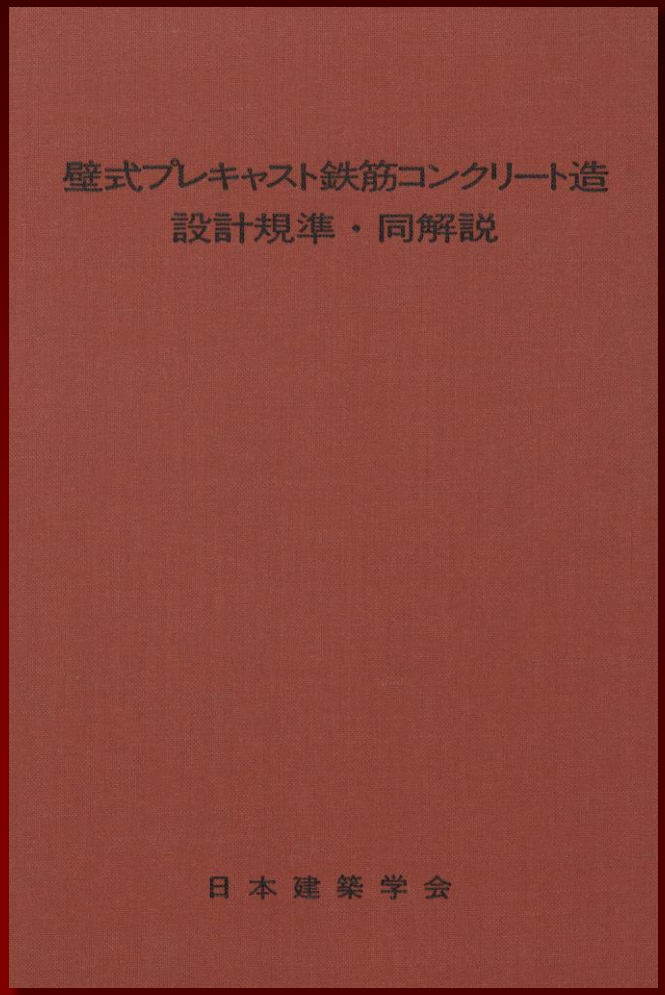
large precast concrete panel

AIJ
Standard for Structural Design of Precast Concrete Structural Wall Building, 1965



- story : up to 4 (currently 5)
- maximum height : <= 15m (currently 20m)
- story height : <= 3m (currently 3.5m)

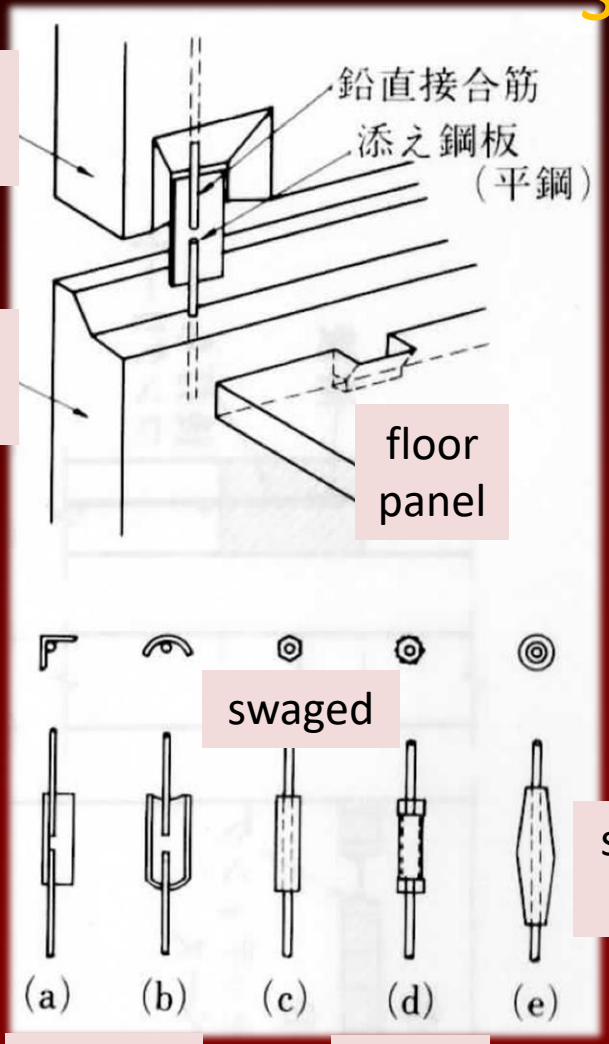
AIJ
Japanese Architectural Standard Specification, JASS 10
Precast Reinforced Concrete Work for Structural Wall buildings, 1965

toward high- and mid-rise precast wall buildings

- 1970s : *SPH*: Standard Public Housing
  - standardization in plan, members and structural system, ... for higher productivity
  - approximately 120,000 units
- 1968 and 1973: loading tests on 5- and 8-story real-size prototype precast buildings
- 1974: first 8-story precast building construction

5-story precast wall building

high- and mid-rise precast wall buildings: *stiff and strong connections*



structural wall

structural wall

floor panel

swaged

sleeve with grout

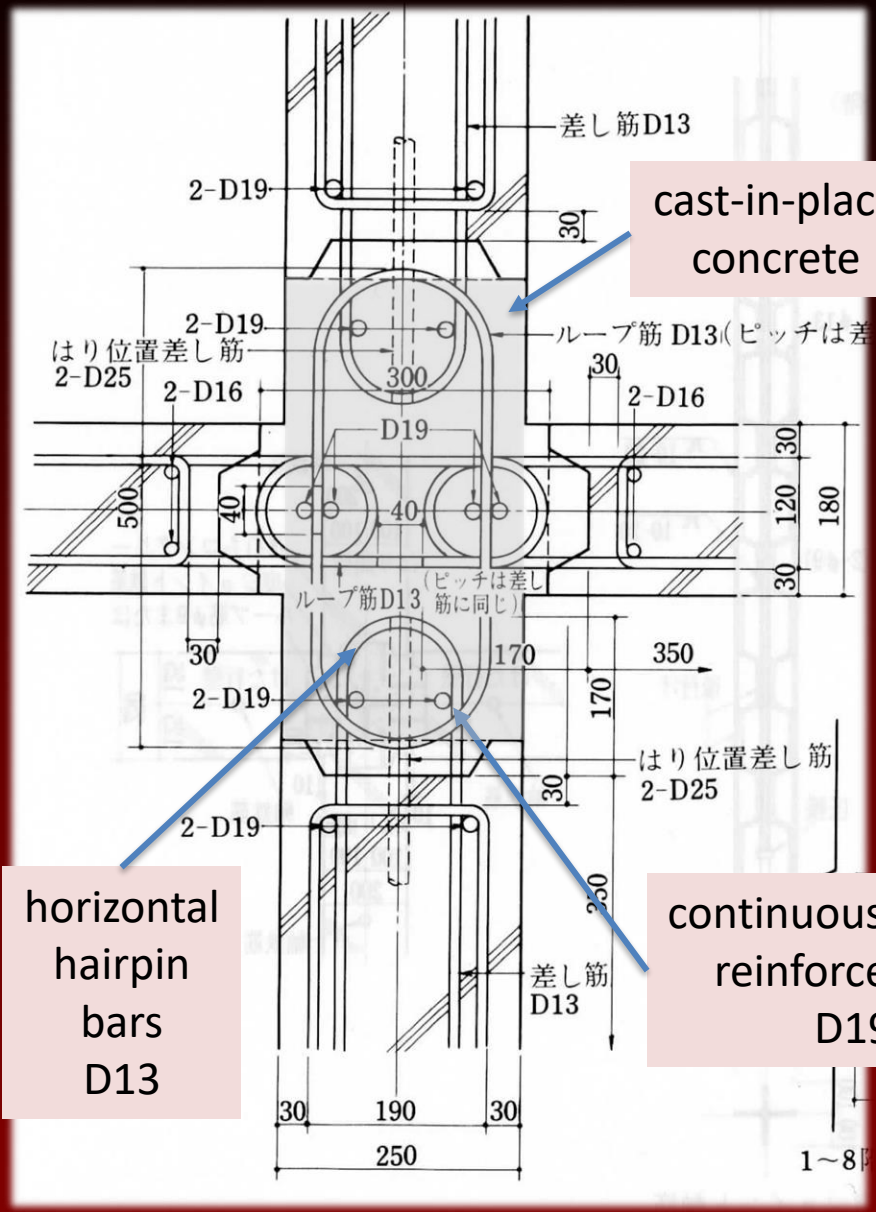
welding

screw

stronger and stiffer connections for vertical reinforcing bars in walls to resist larger shear, axial force and bending moment to be induced in lower stories

high- and mid-rise precast wall buildings

stronger and stiffer vertical joint between walls to reduce stiffness degradation even after cracking

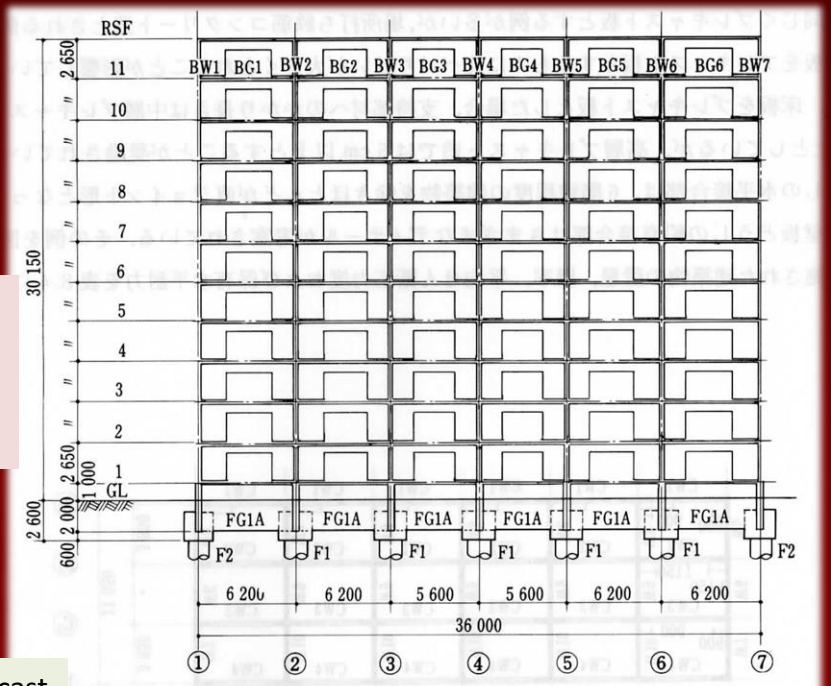


cast-in-place concrete

horizontal hairpin bars D13

continuous vertical reinforcement D19

vertical joint



11-story (30m) prototype building

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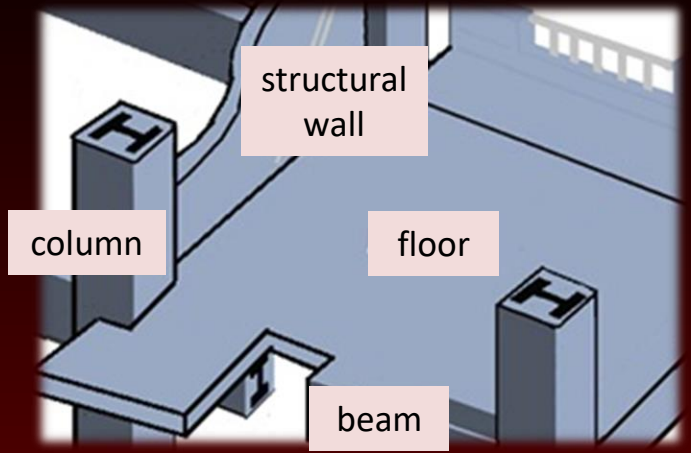
high- and mid-rise precast buildings: *H-section steel*



Kudan Architectural Institute Co., Ltd

Toyoshima 5-chome residential complex

Urban Renaissance Agency

HPC

7- to 15-story

longitudinal direction

moment resisting frame:

cast-in-place column with H-section steel inside

+

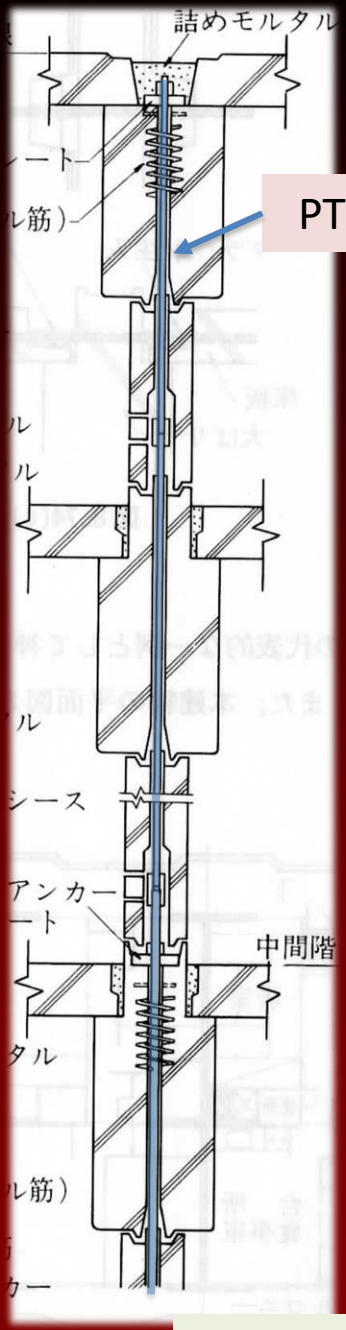
precast beams

transverse direction

wall or steel bracing:

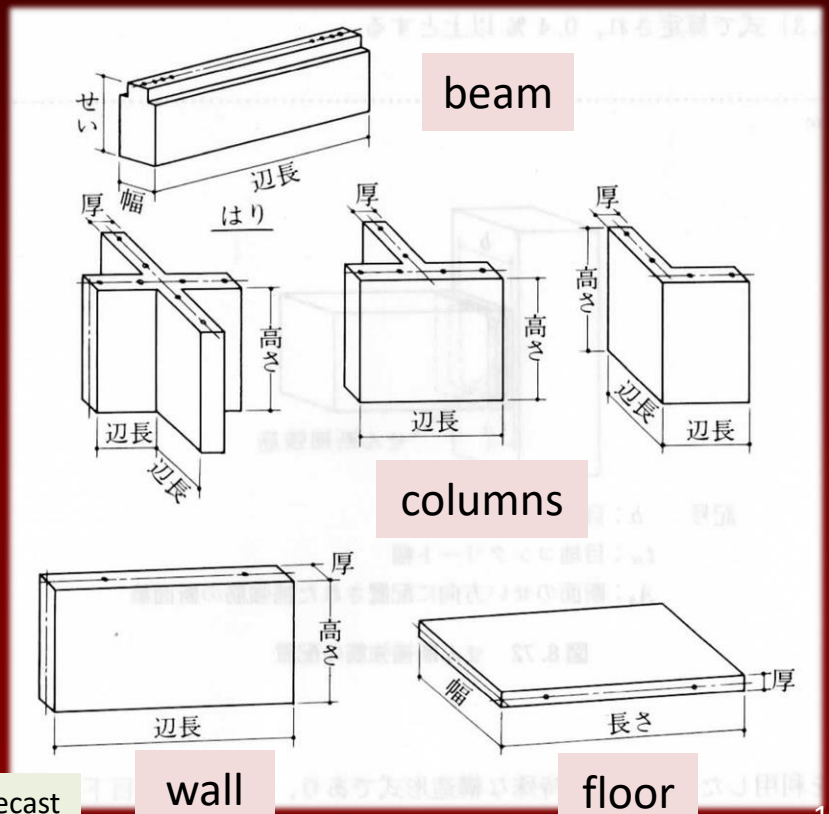
precast floor

high- and mid-rise precast buildings: *post-tensioning*



Guide for Design and Prefabrication of Precast Reinforced Concrete Structures

assembled by post-tensioning
up to 10-story



super high-rise precast moment resisting frame

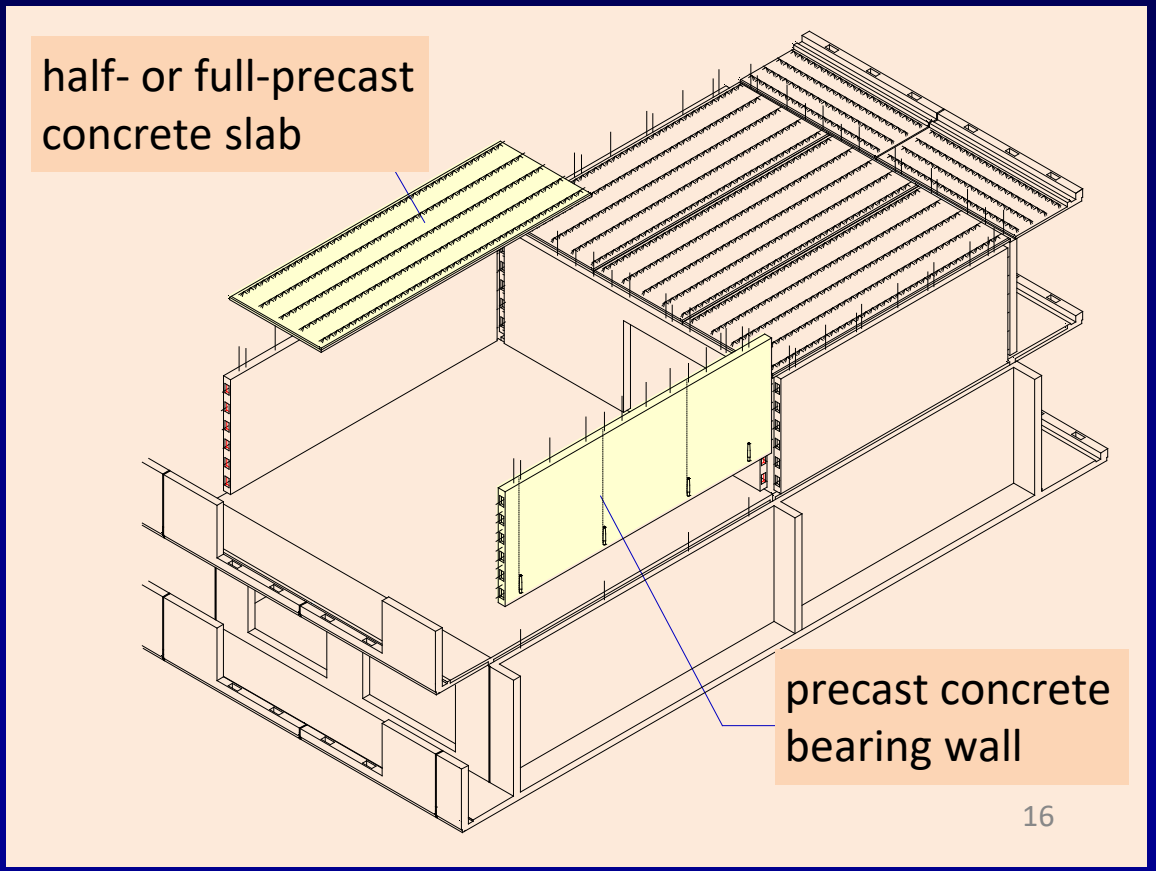
- 1987~1992
  - *New RC project*: Development of Advanced Reinforced Concrete Buildings using High Strength Concrete and Reinforcement
  - concrete and steel strengths: up to 60 and 685 N/mm^2, respectively
- 1988
  - AIJ: Design Guidelines for Earthquake Resistant Reinforced Concrete Buildings Based on Ultimate Strength Concept
- 1989
  - *25-story* precast (beam, floor, wall) concrete building
- 1991
  - *30-story* full precast concrete building
- 1989~
  - *PRESSS*: PREcast Seismic Structural System

current precast housing structures specified in *JASS10*

- Four types of buildings:
  - Wall Precast Concrete (WPC): *Non-ductile*
  - Rahmen Precast Conrete (RPC) (precast concrete moment resisting frame): *Ductile*
  - Wall Rahmen Precast Concrete (WRPC) (precast concrete moment resisting frame with walls): *Limited-ductility*
  - Precast Steel Reinforced Concrete (SRPC): *Ductile*

Wall Precast Concrete (WPC)

- no. of stories <= 5
- total height <= 20m
- story height <= 3.5m



WPC: assembling process

precast wall

precast slab

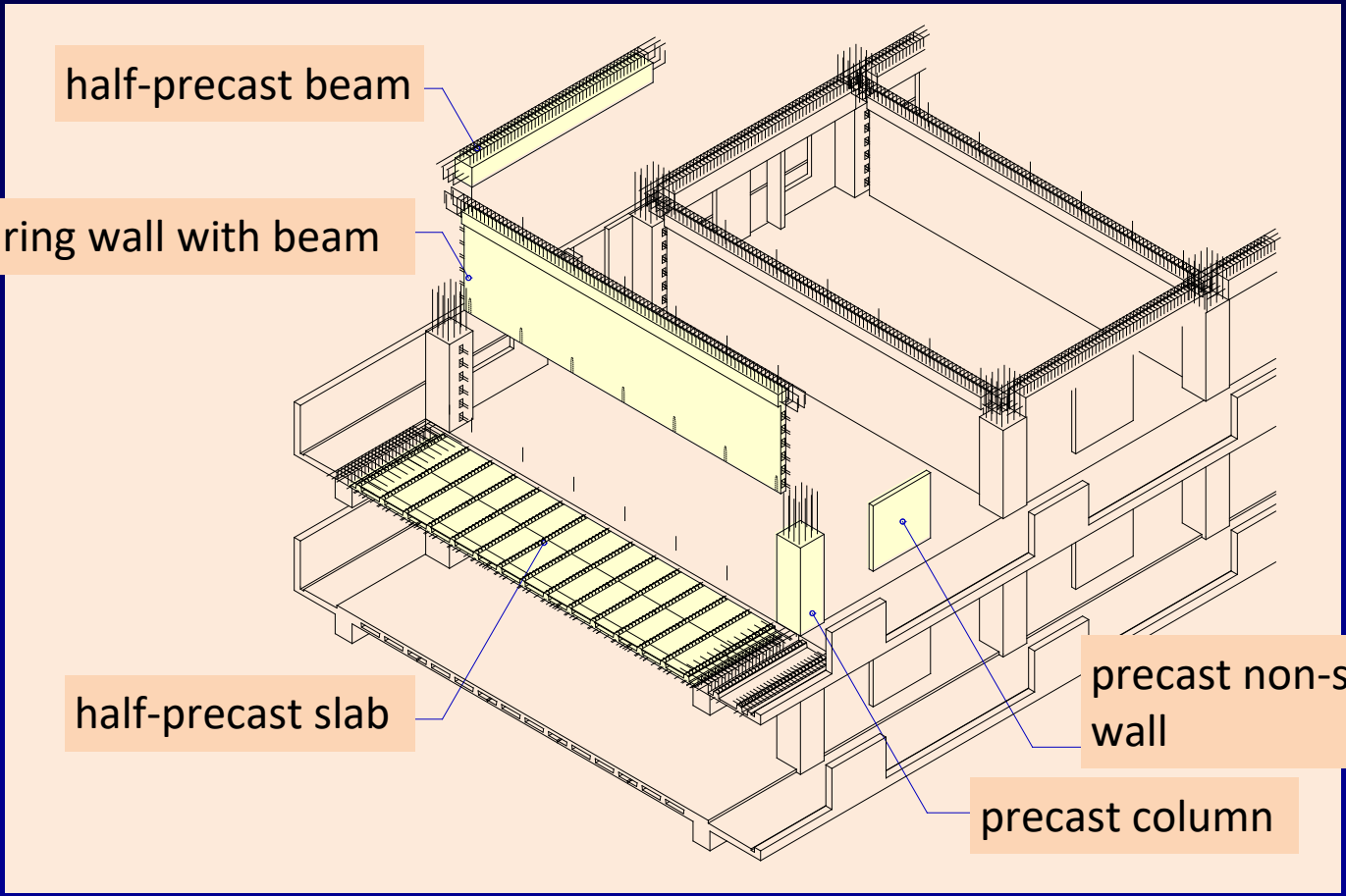
precast balcony

re-bar arrangement

cast-in-place concrete

Rahmen Precast Concrete (RPC)

- precast concrete moment resisting frame
- high- and mid-rise buildings



RPC: assembling process

precast column

wall with beam

precast beam

precast slab

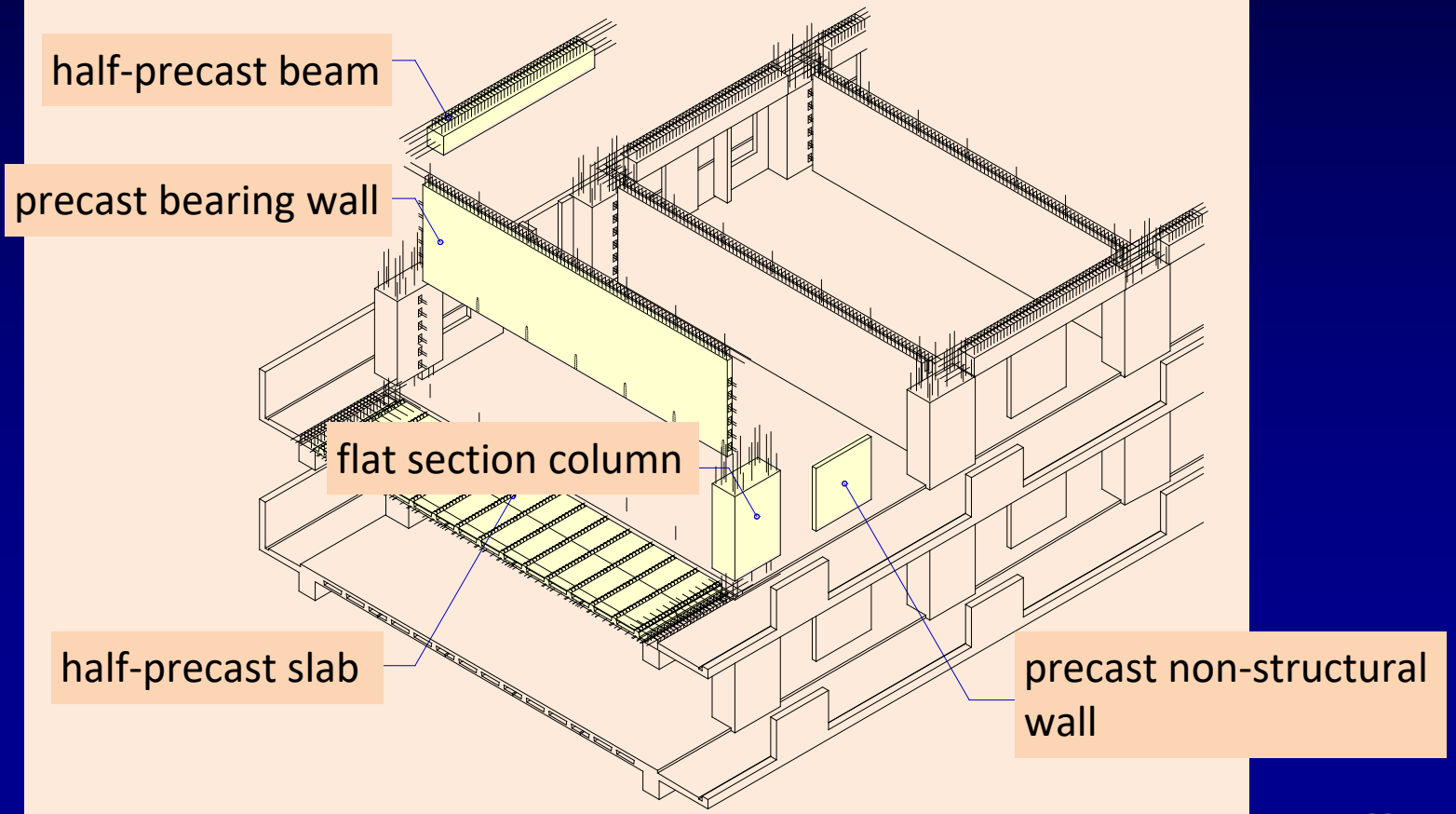
precast balcony

re-bar arrangement

cast-in-place concrete

Wall Rahmen Precast Concrete (WRPC)

- no. of stories <= 15
- total height <= 45m



Damage to Precast/Prestressed Concrete Building Structures due to

Great Hanshin-Awaji Earthquake on January 17, 1995 and Great East Japan Earthquake on March 11, 2011

Great Hanshin-Awaji Earthquake on January 17, 1995

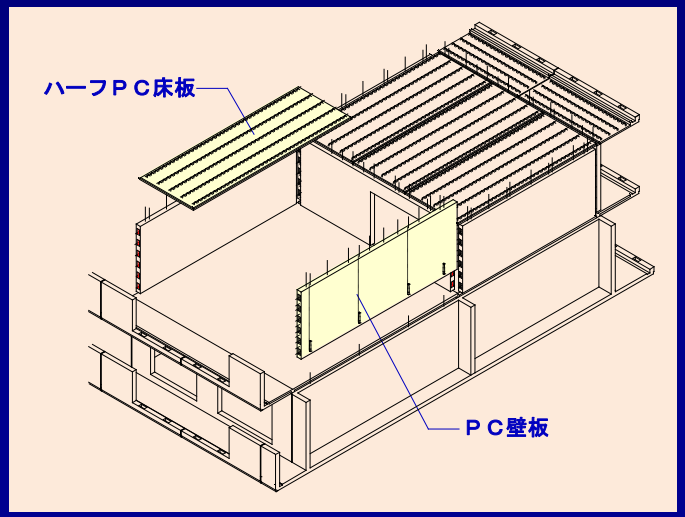
- Two gymnasiums had precast prestressed concrete roof panels *Silberkuhl* fallen.

Damage statistics of precast and/or prestressed concrete buildings
- schools, gymnasiums and warehouses -

	damage level as a whole building						
damage level as a member	collapse	severe	moderate	minor	slight	no	total
collapse	1*1	1*2	0	0	0	0	2
severe	0	0	0	0	0	0	0
moderate	0	0	0	0	0	0	0
minor	0	1*3	0	1	0	0	2
slight	0	0	0	0	9	0	9
no	0	2*4	1*5	5	38	240	286
total	1	4	1	6	47	240	299

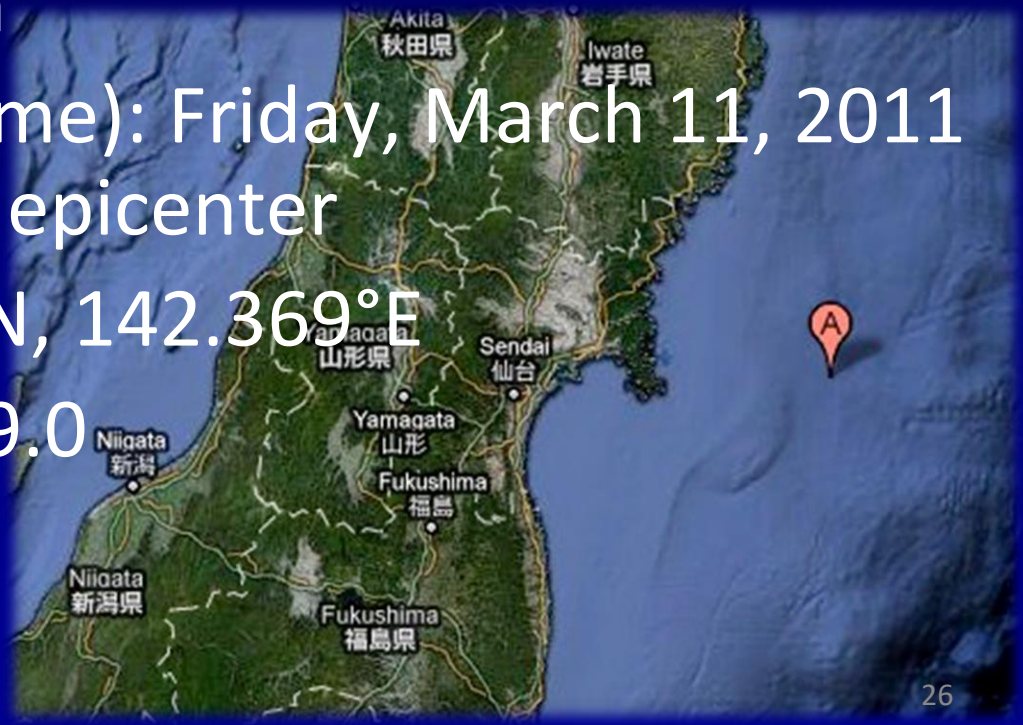
Damage to precast reinforced concrete *low-rise residential* buildings

- Another committee of AIJ inspected approximately 2,000 precast reinforced concrete apartment buildings. These buildings inspected are called *WPC* or Wall Precast Concrete, whose bearing walls, floors, roof, and stairs are precast members.
- In summary, 98.2% of the buildings inspected had no damage. Their high seismic performance was clarified by the inspection results.



Great East Japan Earthquake on March 11, 2011

- The 2011 off the Pacific coast of Tohoku (north-east) Earthquake
  - Affected Region: The east coast of Honshu (main land), Japan
  - Date-Time(local time): Friday, March 11, 2011 at 02:46:23 pm at epicenter
  - Location: 38.322°N, 142.369°E
  - Magnitude(Mw): 9.0
  - Depth: 32 km

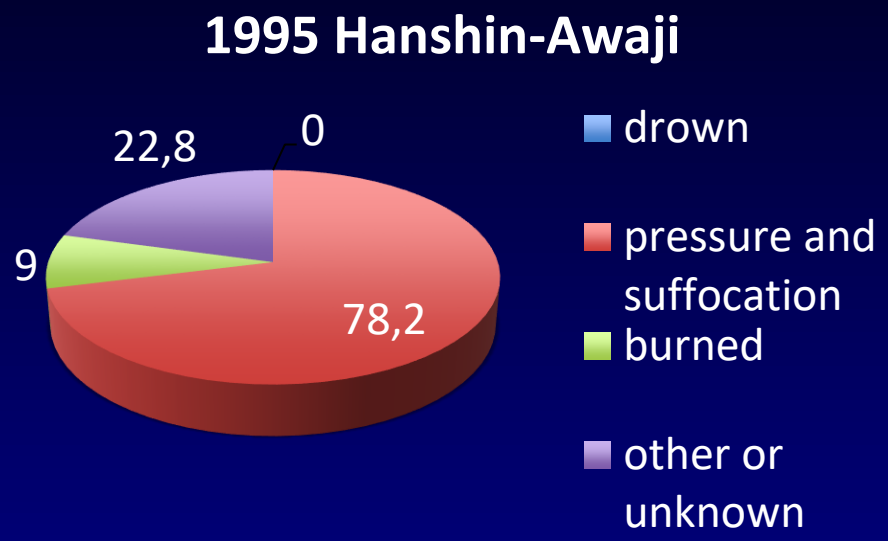


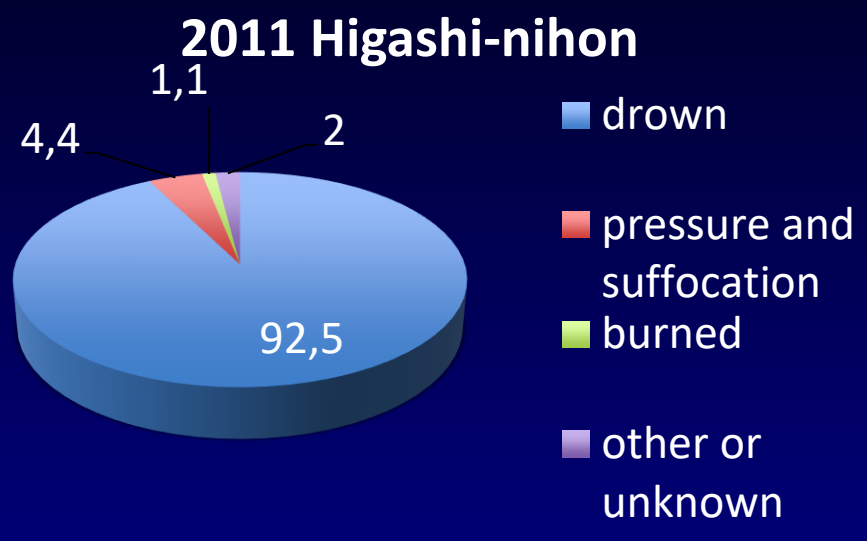
damage statistics

- The death toll: 15,899 (as of March 9, 2021)
- The missing: 2,526 (as of March 9, 2021)
- Buildings (as of Dec. 10, 2020):
  totally collapsed: 121,992
  partially collapsed: 282,920

- 1995 Hanshin-Awaji earthquake
  - the death toll: 6,400
  - the injured: 40,000
  - Buildings collapsed: 94,000
    - severely damaged: 107,000
  - Total property loss: 9.9 trillion yen

causes of casualty





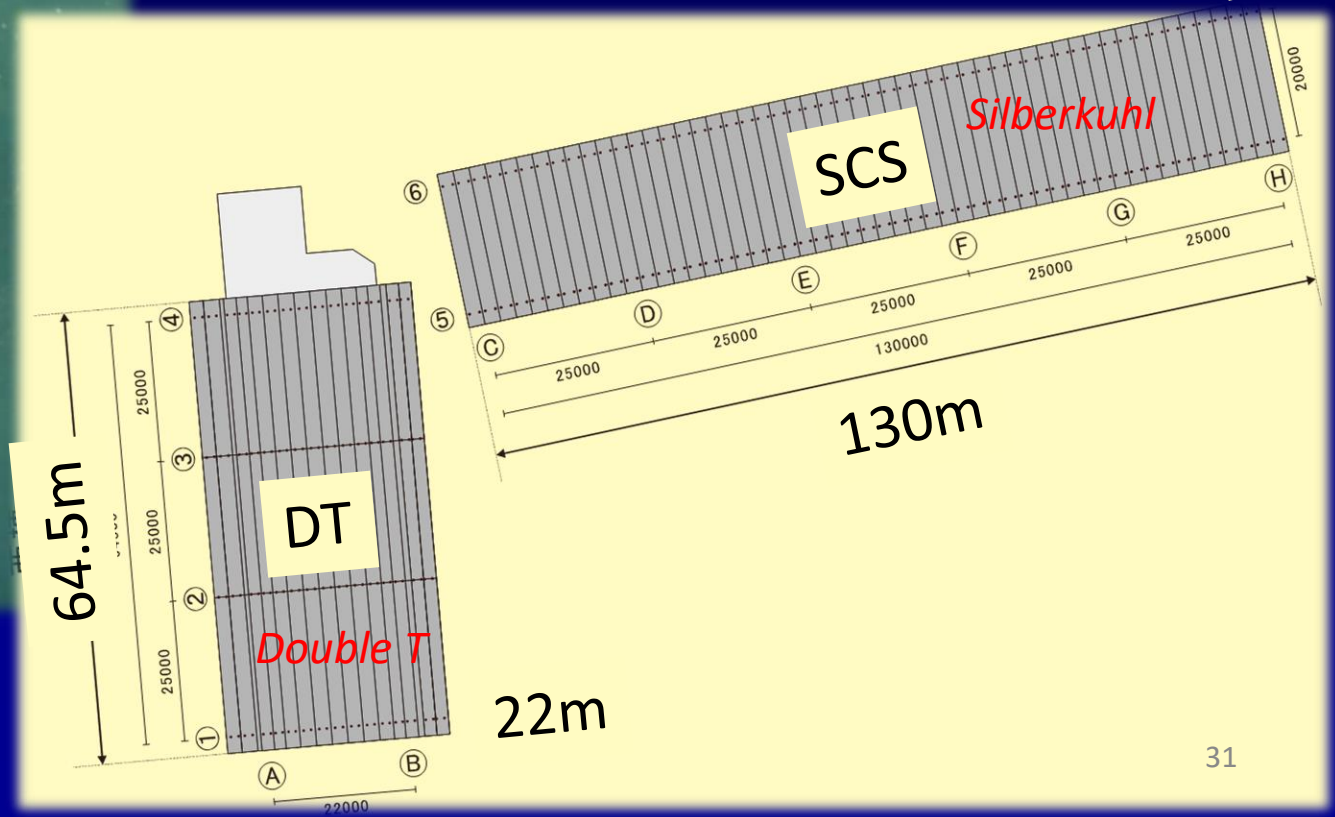
- Lessons from 1995 Hanshin-Awaji earthquake
  - For the life safety the buildings should be prevented from collapsing or fire burning.
  - The response (acceleration or velocity) of the buildings must be controlled to prevent heavy furniture and equipment from overturning on the floor or to prevent heavy equipment from falling from shelves. -> base-isolation
  - The content of the buildings should be properly fastened to them.

Onagawa, Miyagi pref.

- The innermost of a bay on the sawtooth (ria) coastline (Sanriku Kaigan)
- The maximum water depth of the tsunami above the ground level is estimated 14m.

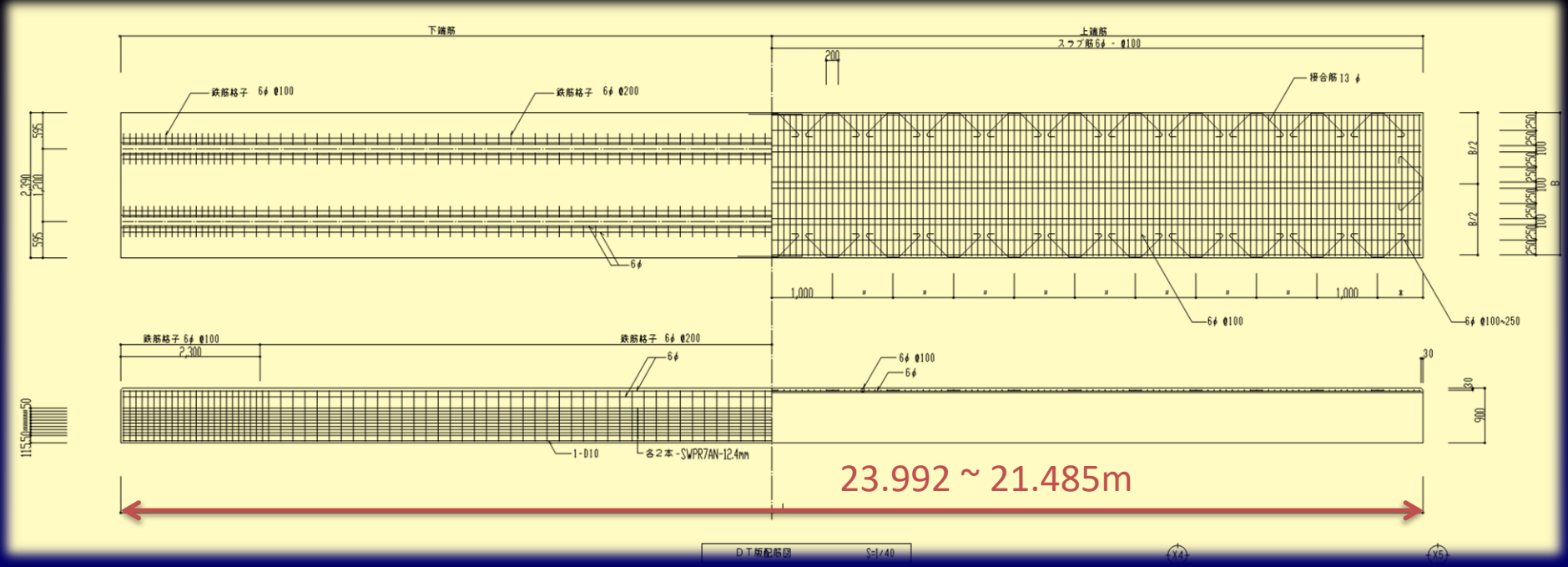
fish market in Onagawa after the eq

fish market in Onagawa

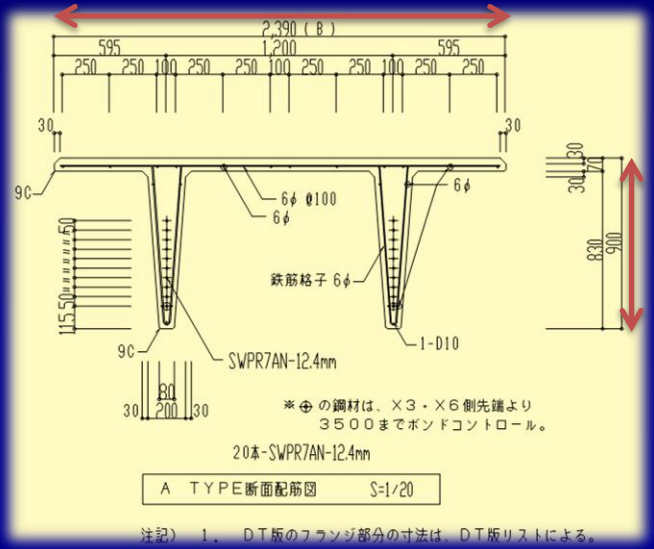


building summary

- Designed and built in 2002
- Plan: 3 x 21.5m + extension by 22m
- The height: 11.45m
- Post-tensioned beams in both directions
- 15 x DT panels in the one longitudinal span
  - width: 2.39 ~ 1.93m
  - length: 23.992 ~ 21.485m
  - weight: ???



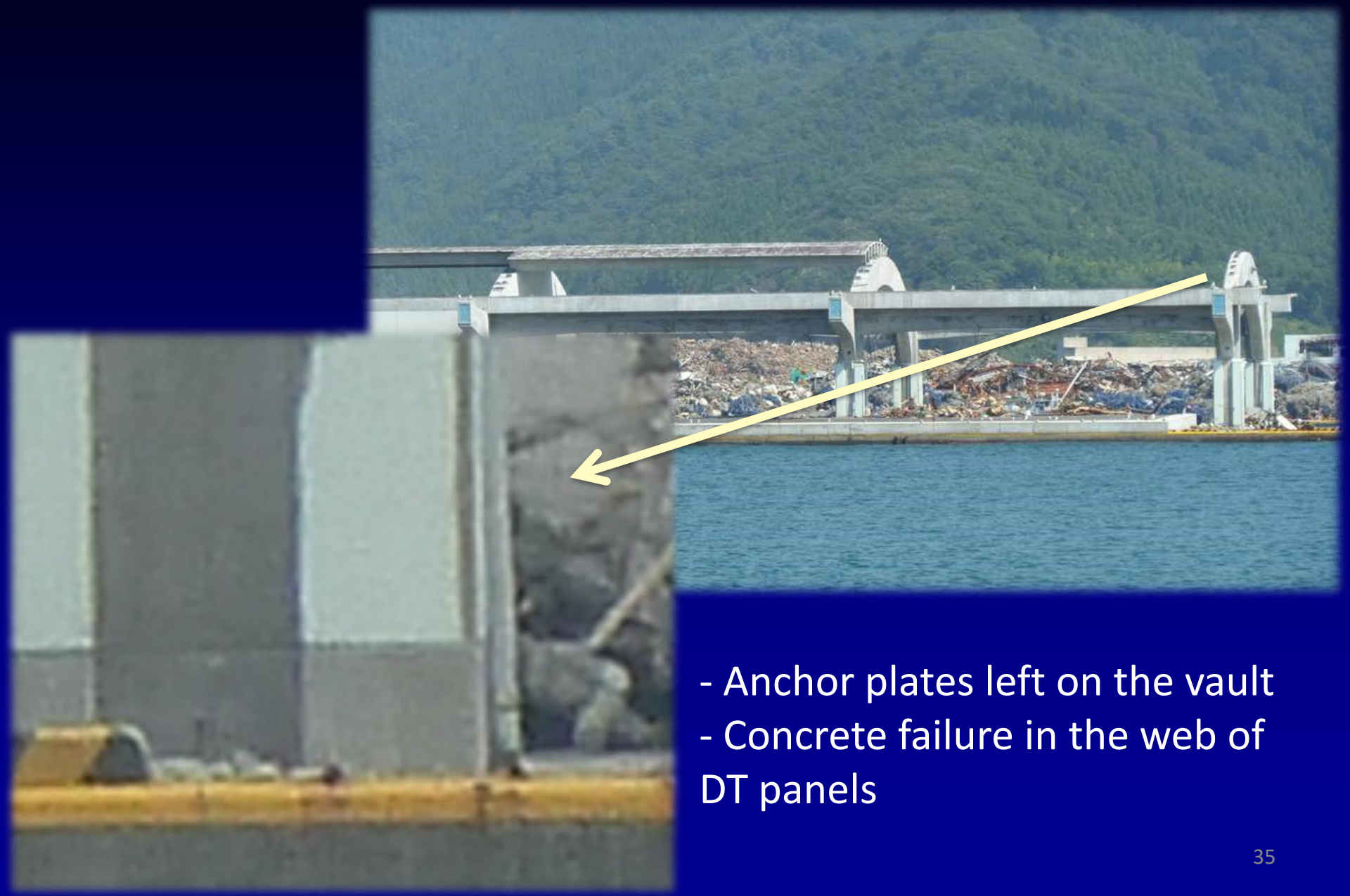
2.39 ~ 1.93m



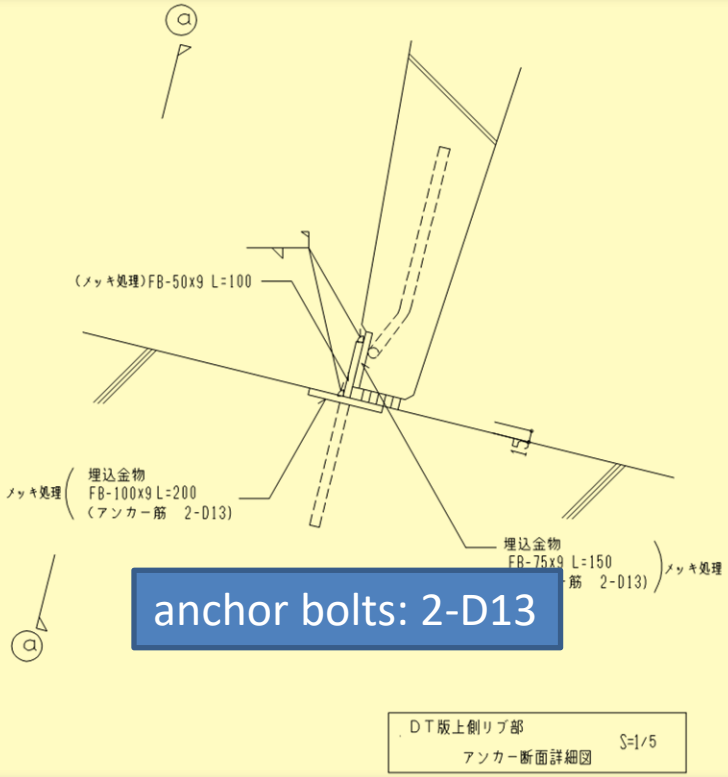
0.9m

- DT panels:
  - Fc = 50 N/mm^2
  - SWPR7AN-12.4mm
    - Py = 136.0 kN/cable

connections



- Anchor plates left on the vault
- Concrete failure in the web of DT panels

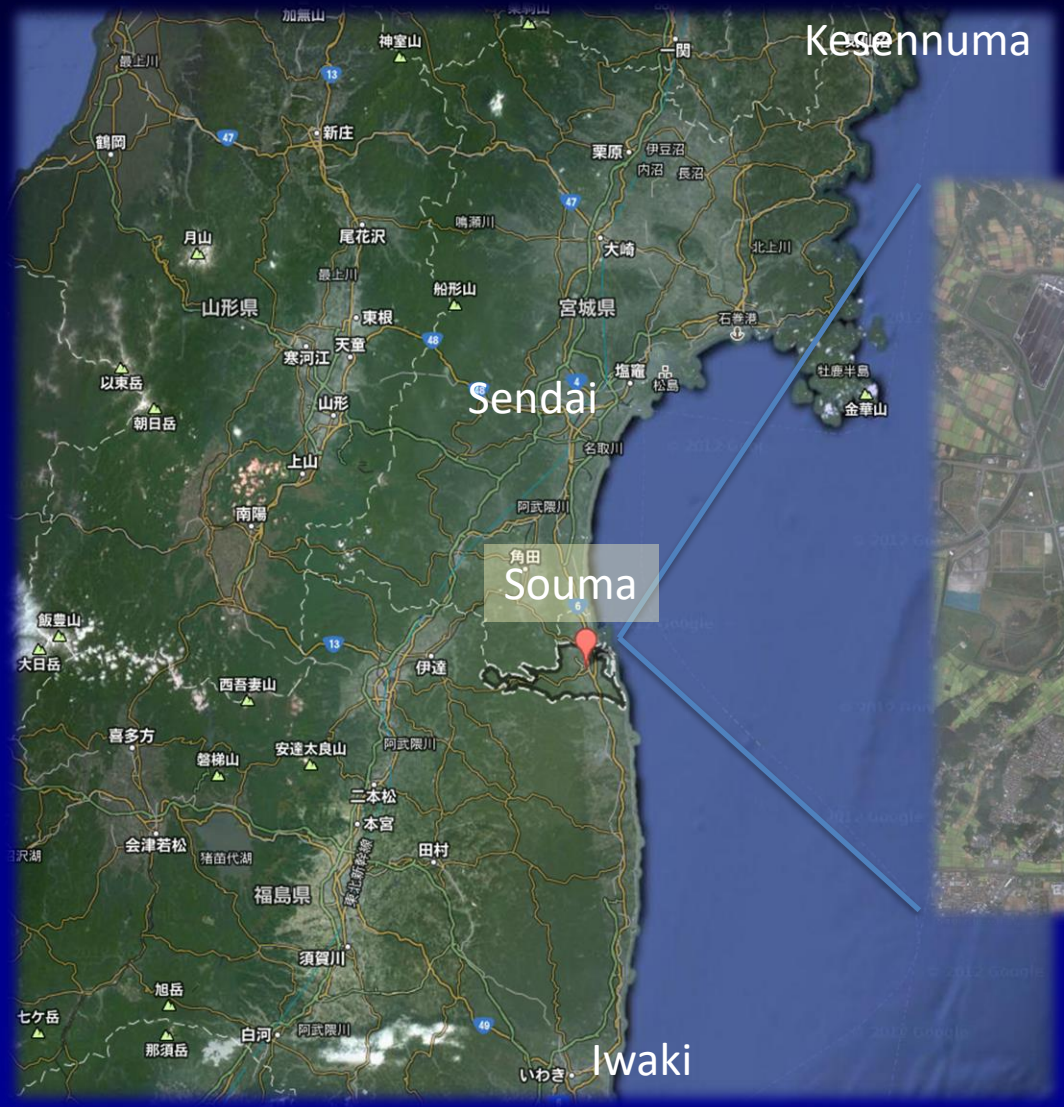


anchor bolt 2-D13 : Py = 254mm^2 x 235N/mm^2 = 59.7 kN

anchor bolt 2-M22 : Py = 774mm^2 x 235N/mm^2 = 181.9 kN

Total Py: 2x241.6 kN = 483.2 kN

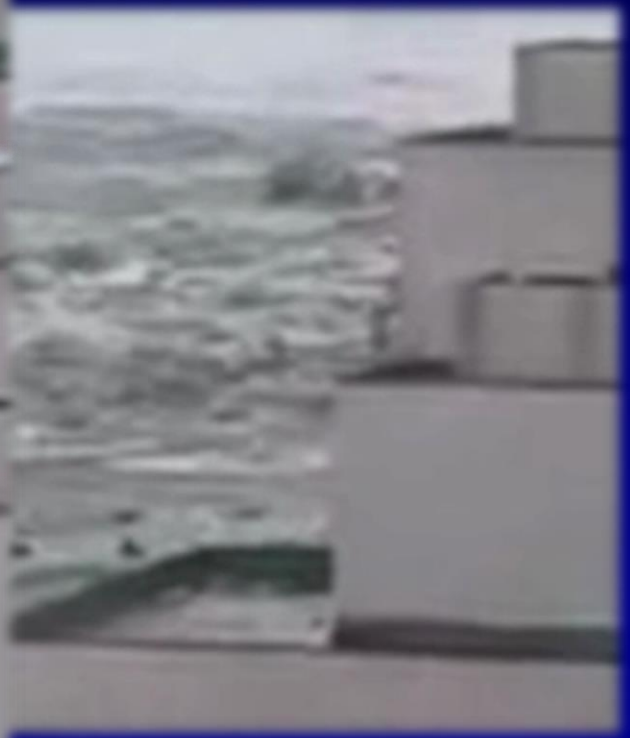
damage by the tsunami fish market in Souma



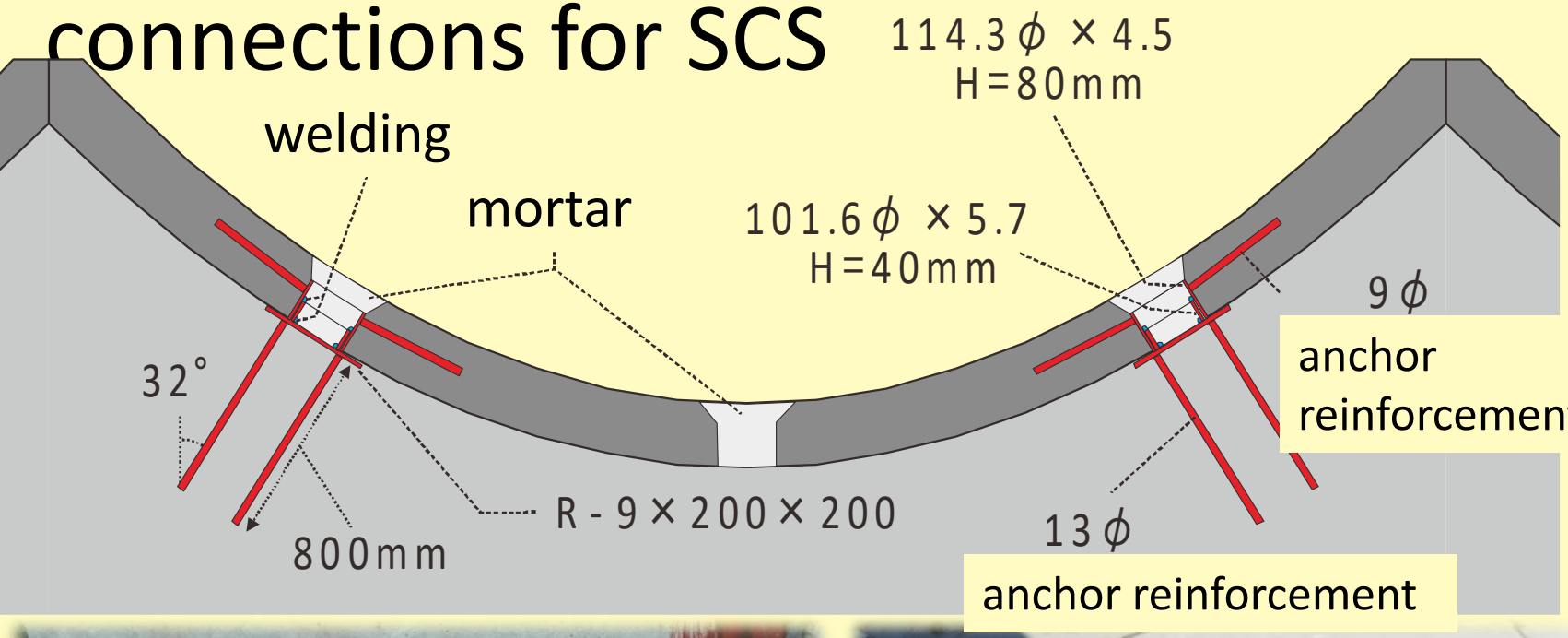
seismic intensity of 6 lower

before and after 3.11

damage to SCS roof panels



connections for SCS



Precast prestressed concrete from present to future

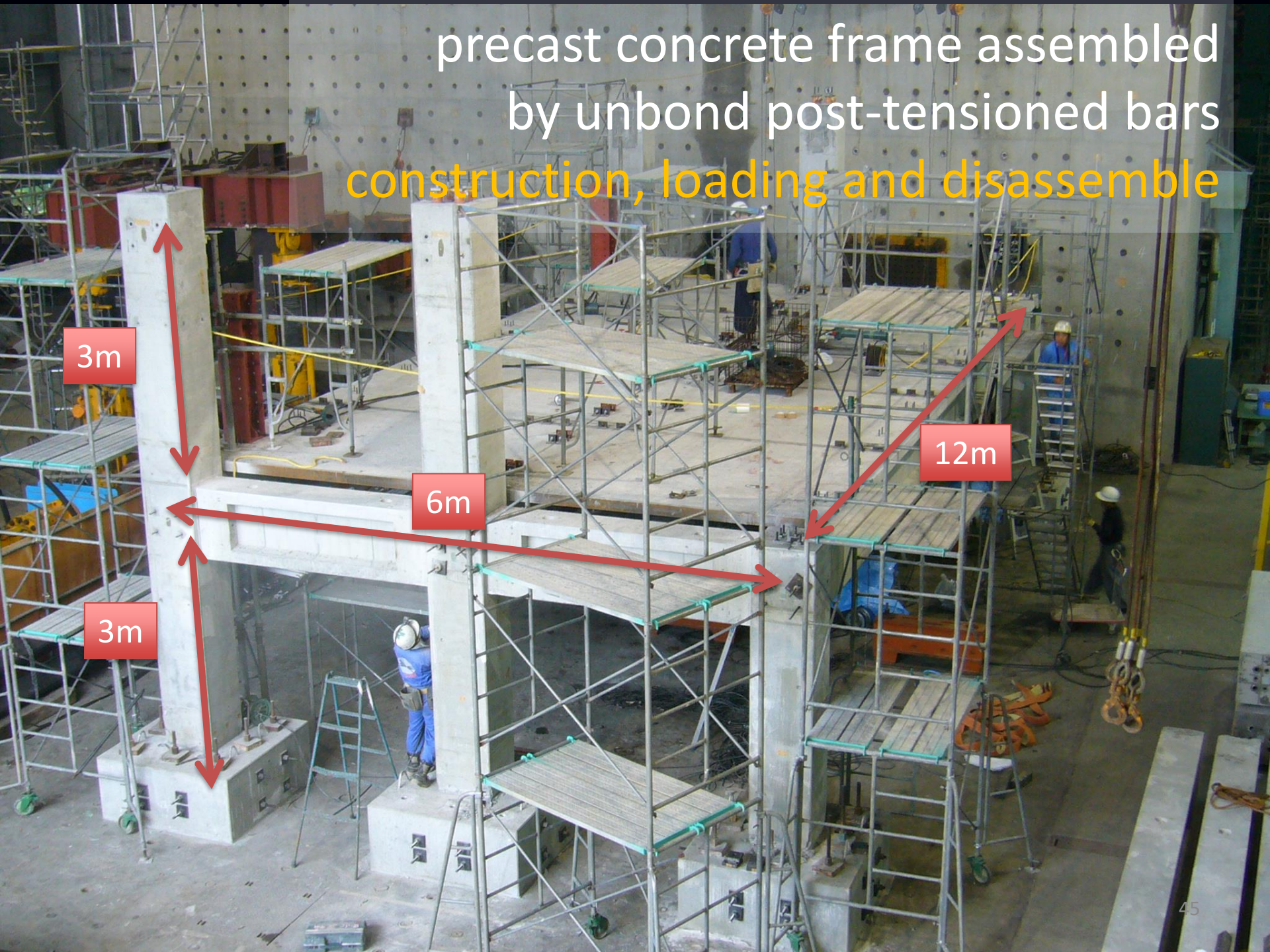
- present

  emulating cast-in-place

- next generation

  precast + prestress

- creation of performance that designers want
  - structural performance under service load: crack and deflection control
  - high durability
  - seismic performance: restorability, hyper-elastic, smaller residual deformation
  - construction ability
  - utilization of high performance materials
  - environment-friendly: energy saving, disassemble-ability

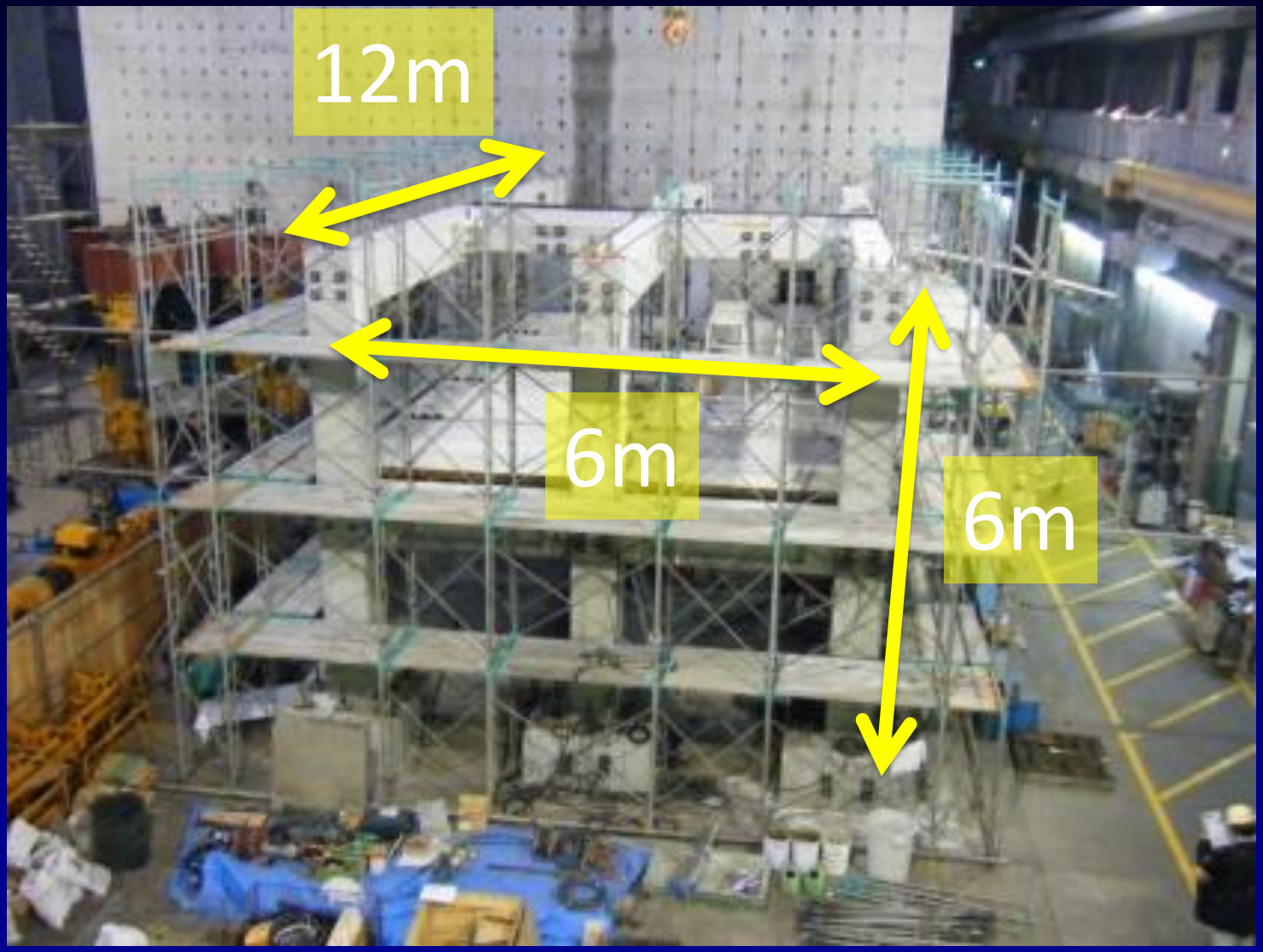

precast concrete frame assembled
by unbond post-tensioned bars
construction, loading and disassemble
3m
6m
12m
3m

foundation blocks

1st floor columns

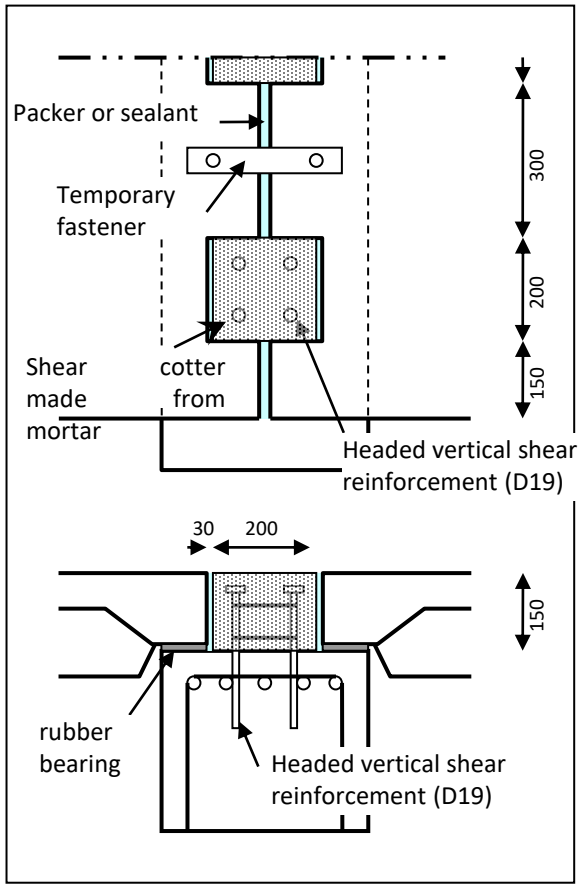
floor slabs installed

completion

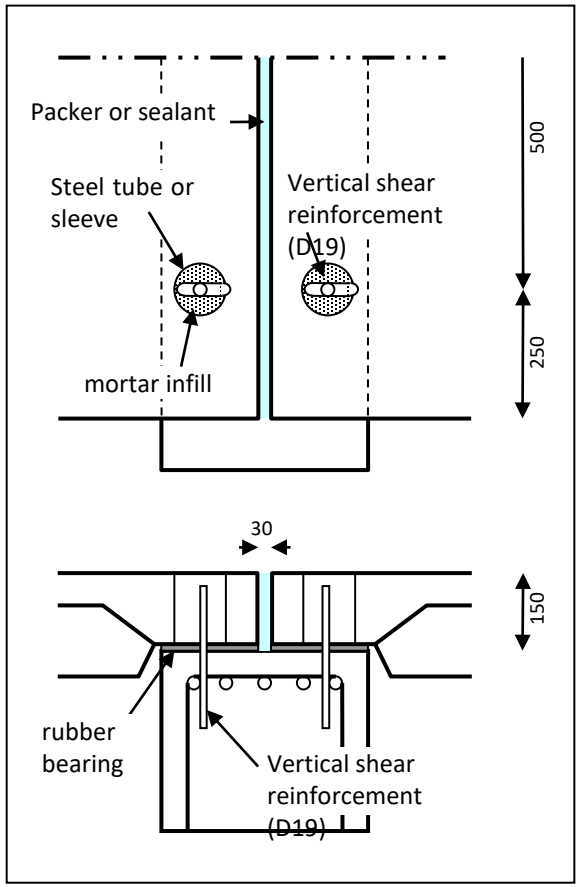


full precast floor systems transferring in-plane shear in one-way and movable in the other way

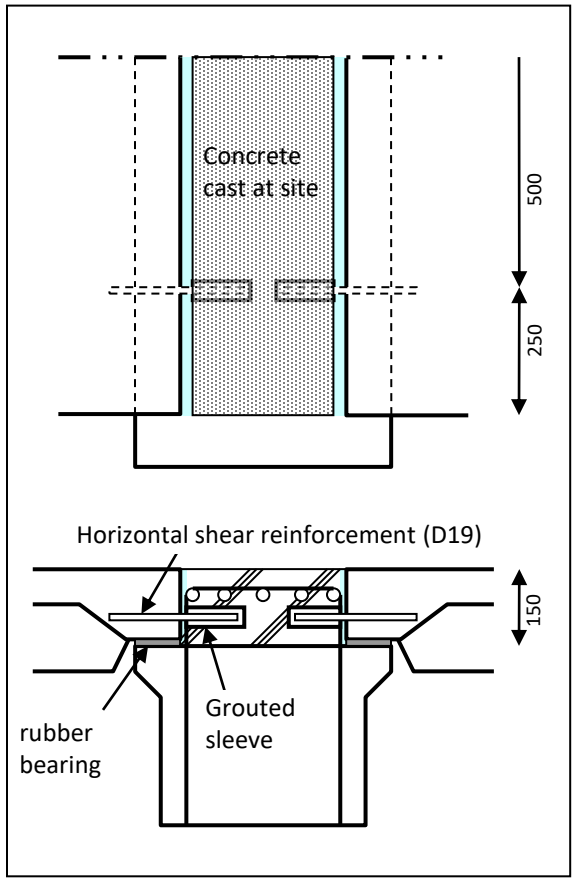
shear cotter (key)



vertical shear reinf. and sleeve



horizontal shear reinf. and sleeve




A-1-2

beam end after disassembled