The Soundness of Unit 4 Reactor Building and Spent Fuel Pool at Fukushima Daiichi Nuclear Power Station

August 30, 2012

Tokyo Electric Power Company

TEPCO 東京電力

Introduction

- Unit 4 reactor building has been damaged by a hydrogen explosion. However, with the progress of debris removal, the necessary conditions for the seismic resistance evaluation have been established as a result of confirming the damage status and developing the design for the cover for fuel removal. For this reason, we conducted a seismic resistance evaluation for the reactor building under the assumption that the spent fuels would be removed from the pool at the end of next year*1.

- In this evaluation, we confirmed that the reactor building, including the spent fuel pool, has a sufficient margin of seismic resistance even when a big earthquake equivalent to the Tohoku-Chihou-Taiheiyou-Oki Earthquake (JMA Seismic Intensity Scale 6+) would occur in the future.

- We will continue to steadily progress towards fuel removal from the spent fuel pool.

*1 : "Report on the Current Seismic Safety and Reinforcement of Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station (No.1) (Supplement)" (August 30, 2012)

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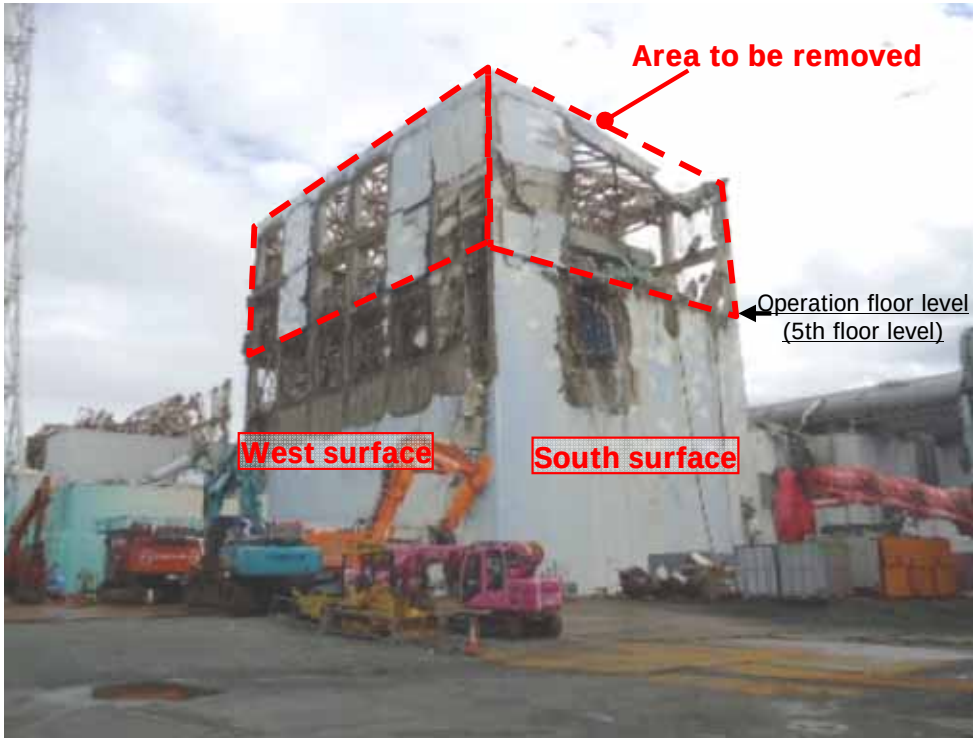
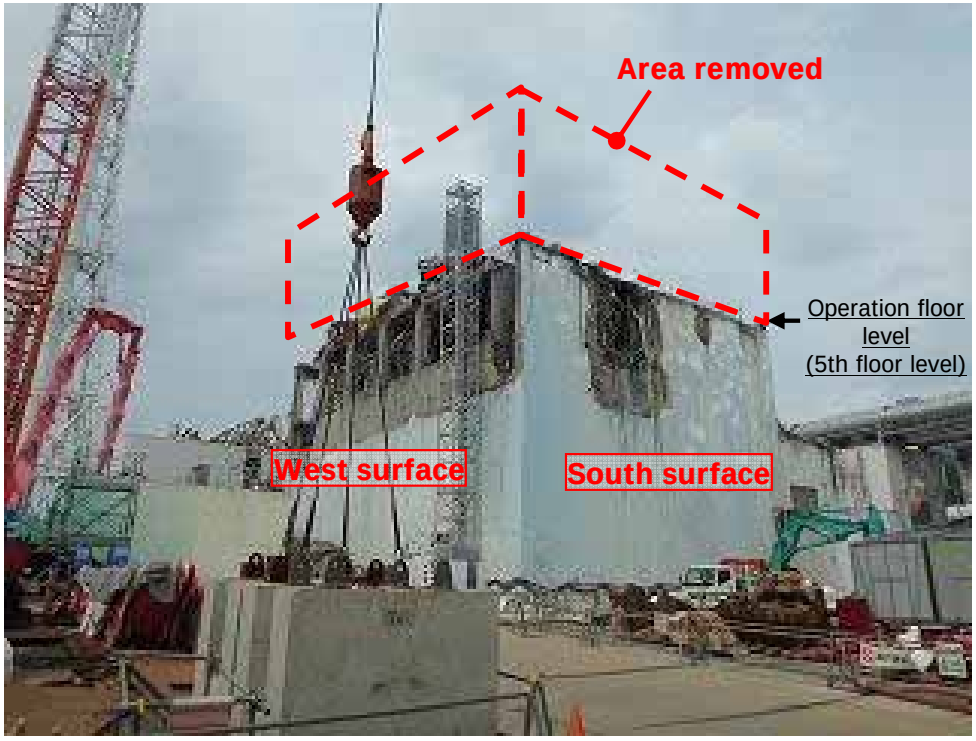
1. Completion of Debris Removal from the Upper Part of Unit 4 Reactor Building

- The debris remaining on the reactor building operation floor such as damaged roof, pillars and beams were completely removed on July 11, 2012.
- Currently, we are in the process of removing large equipments (such as PCV and RPV lids) as scheduled from late July to October 2012.
- After the debris and large equipments are removed, the weight of the upper part of the reactor building will be substantially reduced (to about 4700t).



Operation floor (5th floor level) with debris remaining on it (South and west surfaces)
(Photographed on September 22, 2011)



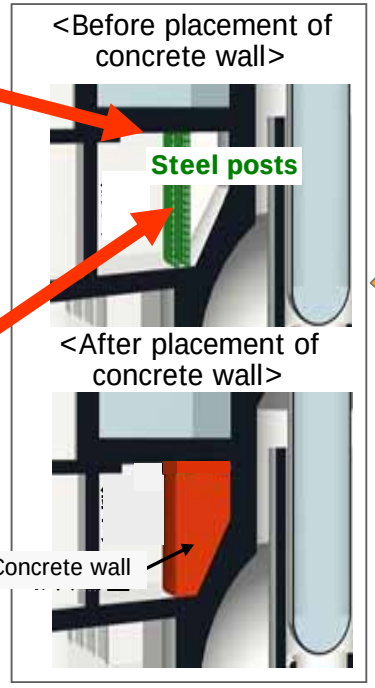
Operation floor (5th floor level) with debris removed (South and west surfaces)
Photographed on July 5, 2012

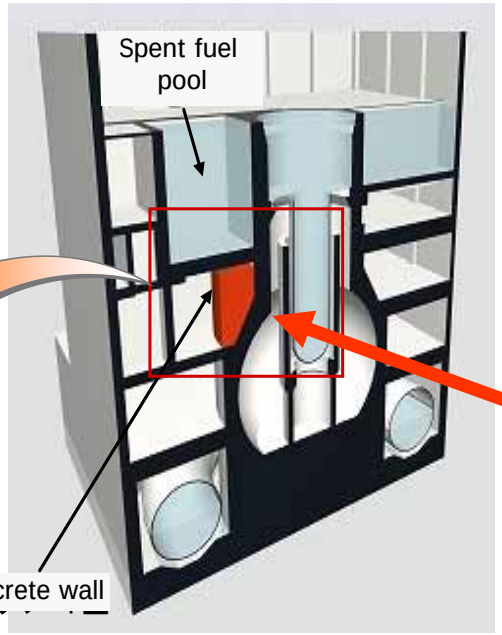
2. Reinforcement of the Bottom of the Spent Fuel Pool

- The evaluation conducted in May 2011 has proved that the spent fuel pool has a sufficient margin of seismic resistance.
- We installed steel posts and a concrete wall to reinforce the bottom of the spent fuel pool which improved the seismic safety margin by 20% compared to the previous structure.

View from the lower floor
(Before placement of concrete wall)*1

Steel posts
(Before placement of concrete wall)*2





Wall supporting the 2nd floor pool structure (Before placement of concrete wall)*3

* Concrete wall (red) was placed after steel posts (green) were installed.

Photos were taken on May 21, 2011, for "*1"; June 15, 2011, for "*2"; and May 20, 2011, for "*3."

3. Damages of the Inside and Outside of the Reactor Building (1)

- As debris removal from the reactor building has progressed, a visual inspection was done to check for damages on the floor slabs and walls.

[Cause of damage]

- The cause of the hydrogen explosion in Unit 4 reactor building is assumed to be hydrogen generated in Unit 3 flowing into the floors of Unit 4 reactor building through pipes and ducts.

[Damage conditions]

Damage conditions of the 3rd, 4th and 5th floor slabs:

- Much damage was found on the relatively thin floor (25 - 30 cm thick) near the duct route, which is assumed to be the location where the hydrogen explosion occurred.

Damage conditions of the 3rd, 4th and 5th floor walls:

- The severity of the damage largely depends on the wall thickness. The walls thinner than 65cm are more damaged compared to those that are thicker.
- **The thick walls of the spent fuel pool and around the PCV that are critical for seismic resistance remained intact.**

[Influence of seawater injection and airborne salt]

- With respect to the areas critical for ensuring seismic resistance, no rust fluid on the rebars due to seawater injection and airborne salt or bulge on the concrete due to rust was found.

[Damage repair]

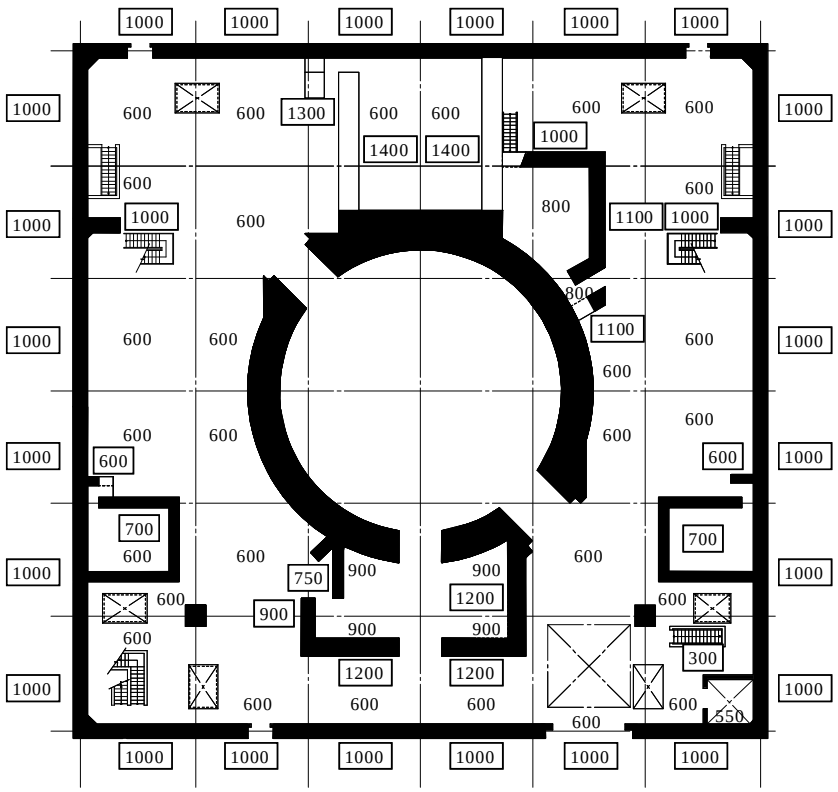
- The damaged parts will be repaired as necessary for durability improvement.

3. Damages of the Inside and Outside of the Reactor Building (2)

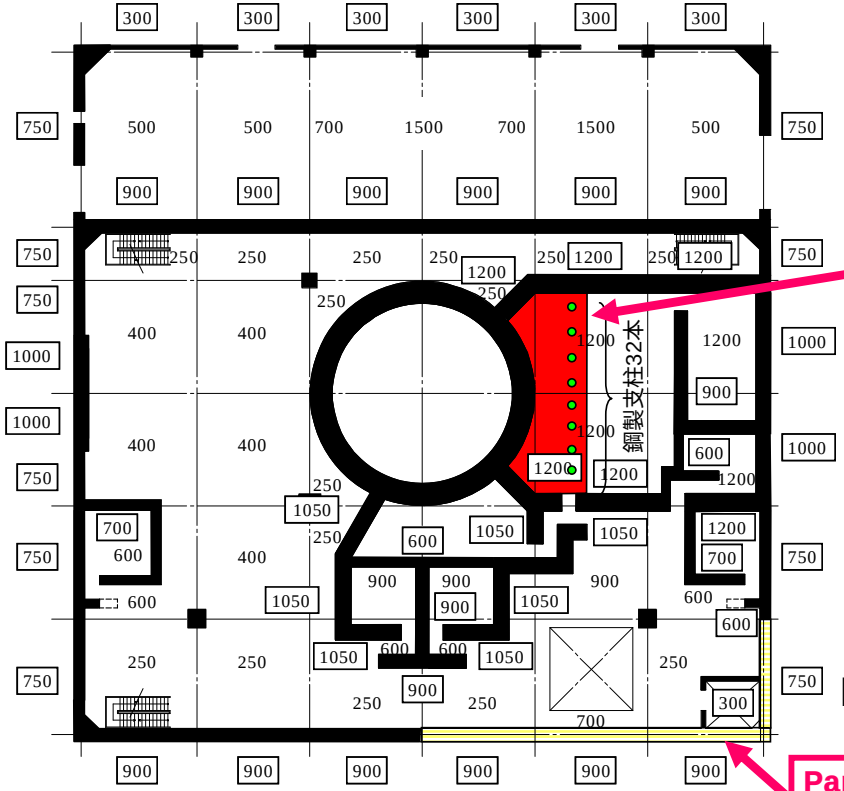
[Damage conditions of the 1st and 2nd floors]

- The floor slabs and the walls were intact as a result of visual inspection*1.

*1 At the regular inspection carried out in May 2012, partial bulge was found on the west and south wall surfaces on the 2nd floor, however, the concrete strength has not decreased and no large crack was found. (“Report on the Seismic Safety of Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station in Consideration of the Partial Bulge on the Exterior Walls” (June 25, 2012))



1st floor - Plan view



2nd floor - Plan view

Legend
: Floor completely destroyed
: Floor partially destroyed
: Walls completely destroyed
: Walls partially destroyed
: Walls remain intact
: Duct route
Numerical value : Wall thickness (mm)
Numerical value : Floor thickness (mm)

3. Damages of the Inside and Outside of the Reactor Building (3)

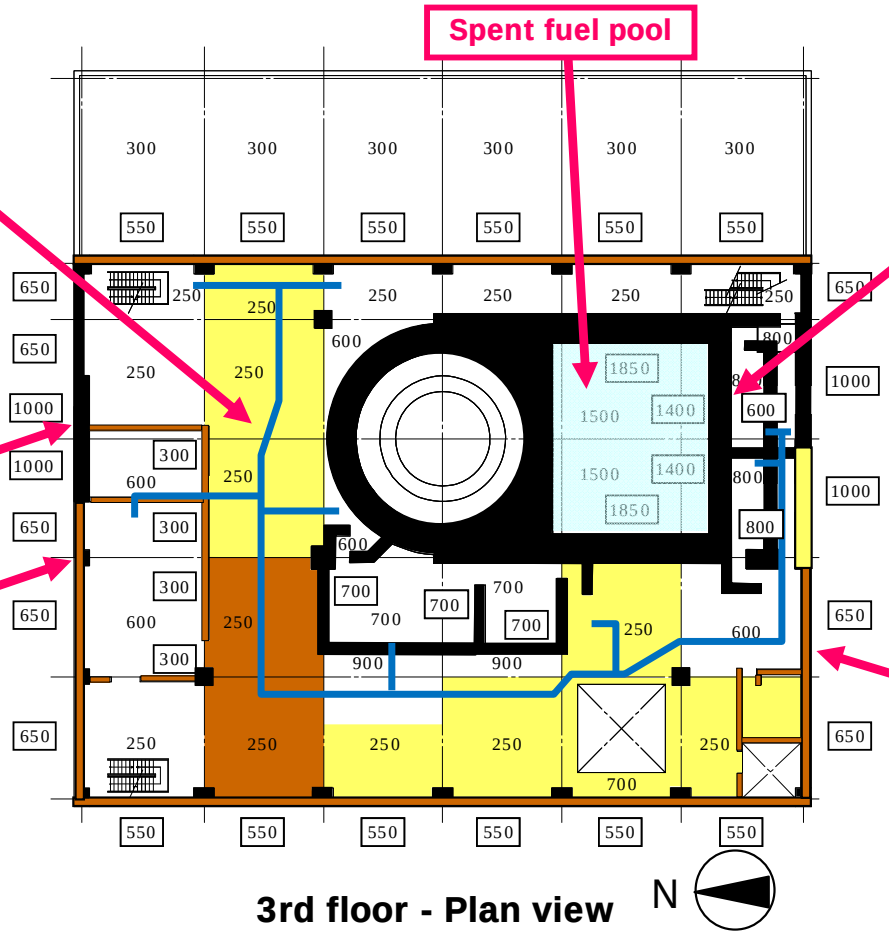
[Damage conditions of the 3rd floor]

Floor damage was found in the area near the duct route

Floor thicker than 25cm: No damage found
Floor thinner than 25cm: More damaged

Walls thicker than 65cm: Less damaged

Walls thinner than 65cm: More damaged



3rd floor - Plan view

Spent fuel pool wall (No damage found)

Exterior wall (Completely destroyed)

Legend
- : Floor completely destroyed
- : Floor partially destroyed
- : Walls completely destroyed
- : Walls partially destroyed
- : Walls remain intact
- : Duct route
- Numerical value : Wall thickness (mm)
- Numerical value : Floor thickness (mm)

3. Damages of the Inside and Outside of the Reactor Building (4)

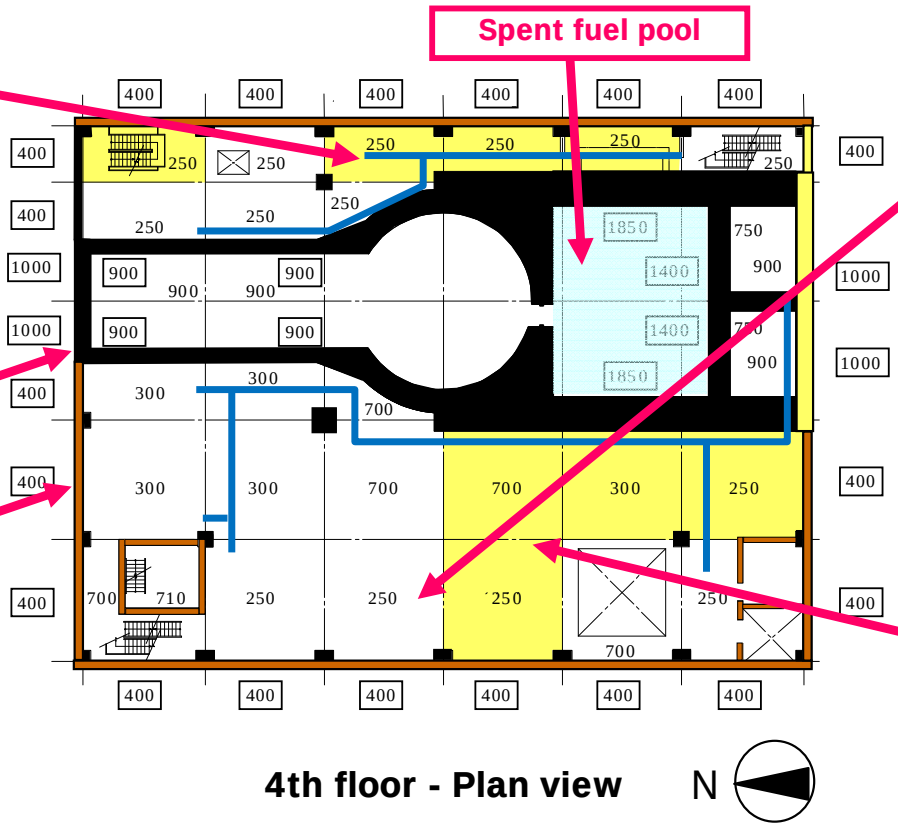
[Damage conditions of the 4th floor]

Floor damage was found in the area near the duct route

Floor thicker than 25cm: Less damaged
Floor thinner than 25cm: More damaged

Walls thicker than 40cm: Less damaged

Walls thinner than 40cm: More damaged



4th floor - Plan view

Floor
(No damage found)

Floor
(Partially damaged)

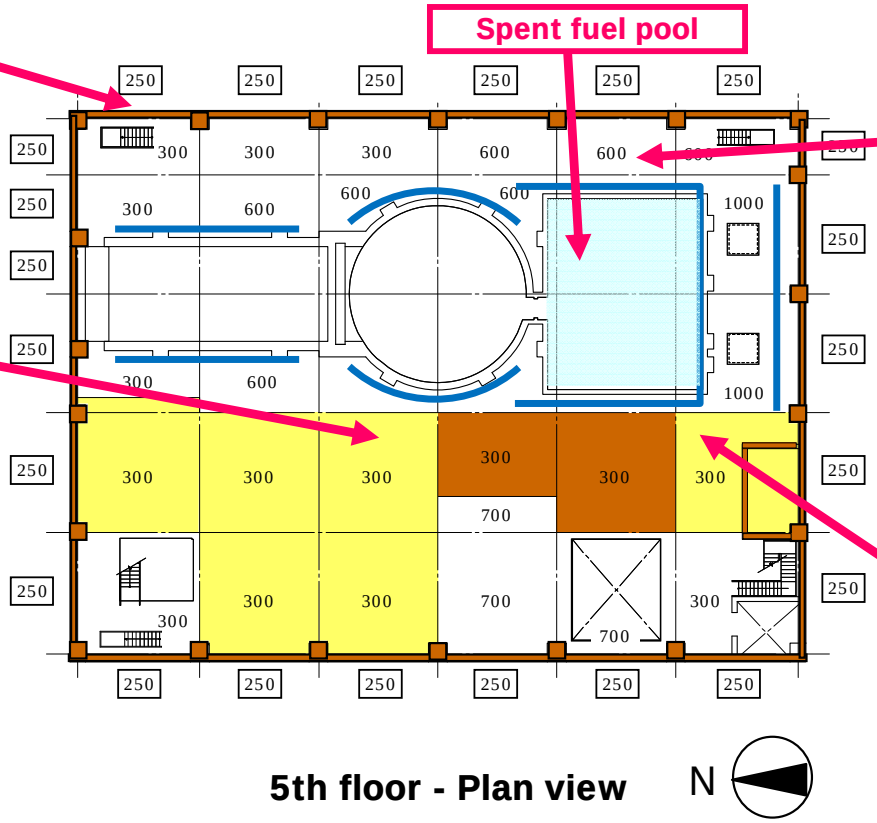
Legend
: Floor completely destroyed
: Floor partially destroyed
: Walls completely destroyed
: Walls partially destroyed
: Walls remain intact
: Duct route
Numerical value : Wall thickness (mm)
Numerical value : Floor thickness (mm)

3. Damages of the Inside and Outside of the Reactor Building (5)

[Damage conditions of the 5th floor]

The walls on the 5th floor and above were removed since they would interfere with the cover to be installed for fuel removal.

Floor thicker than 30 cm: No damage
Floor thinner than 30cm: More damaged



5th floor - Plan view

Floor
(No damage found)

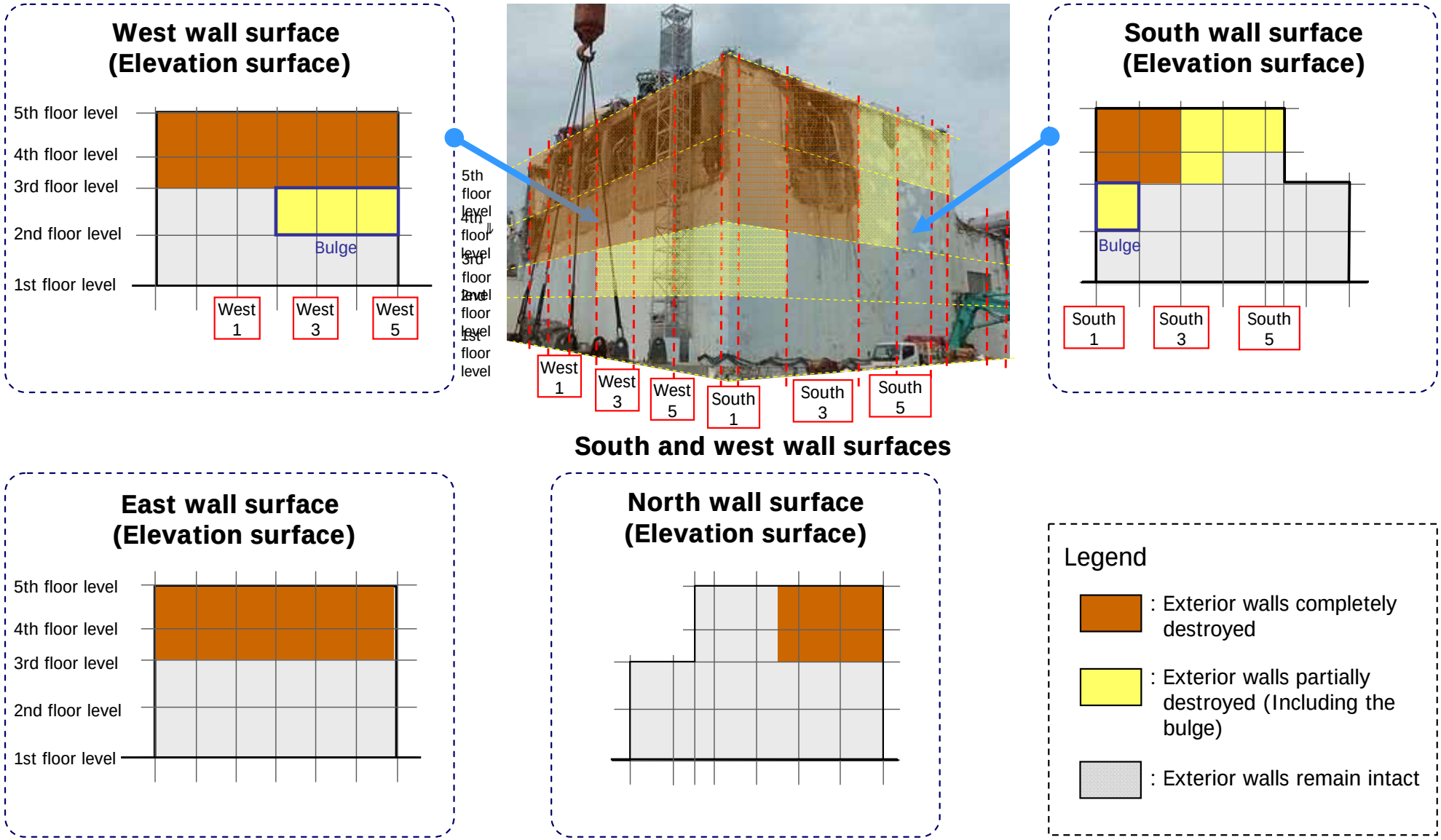
Floor
(Partially damaged)

Legend
: Floor completely destroyed
: Floor partially destroyed
: Walls completely destroyed
: Walls partially destroyed
: Walls remain intact
: Duct route
Numerical value : Wall thickness (mm)
Numerical value : Floor thickness (mm)

3. Damages of the Inside and Outside of the Reactor Building (6)

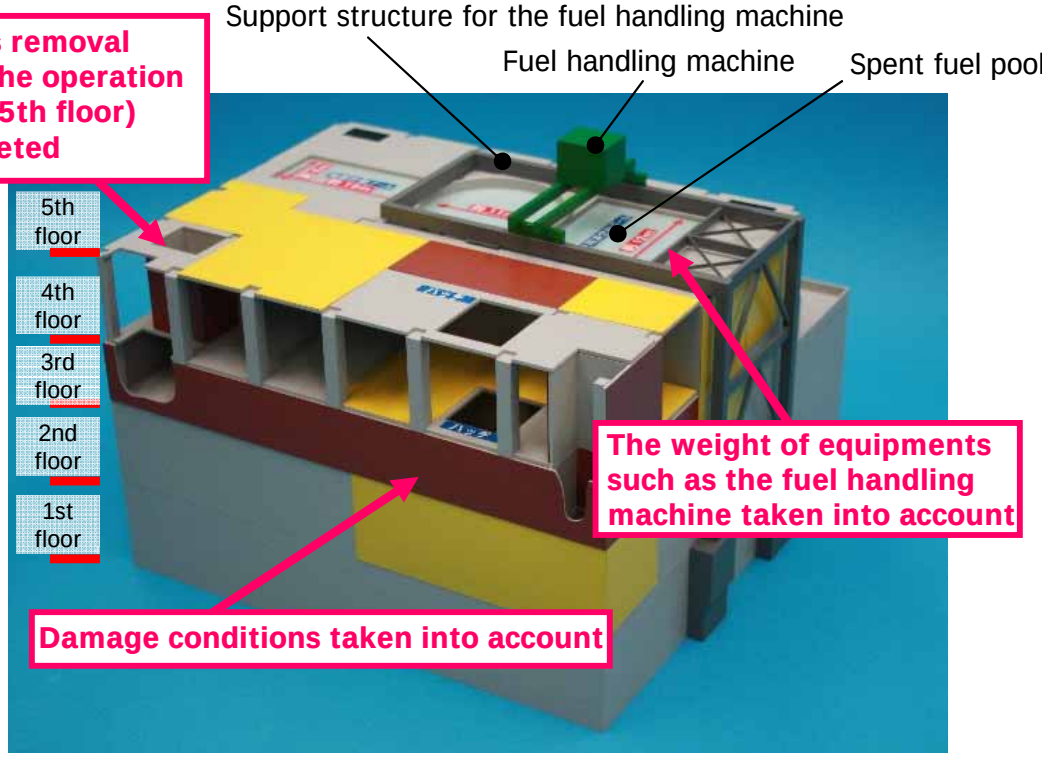
[Damage conditions of the exterior walls]

- The walls on the 3rd floor and above were entirely damaged by the hydrogen explosion, except for a part of the northeast surface.

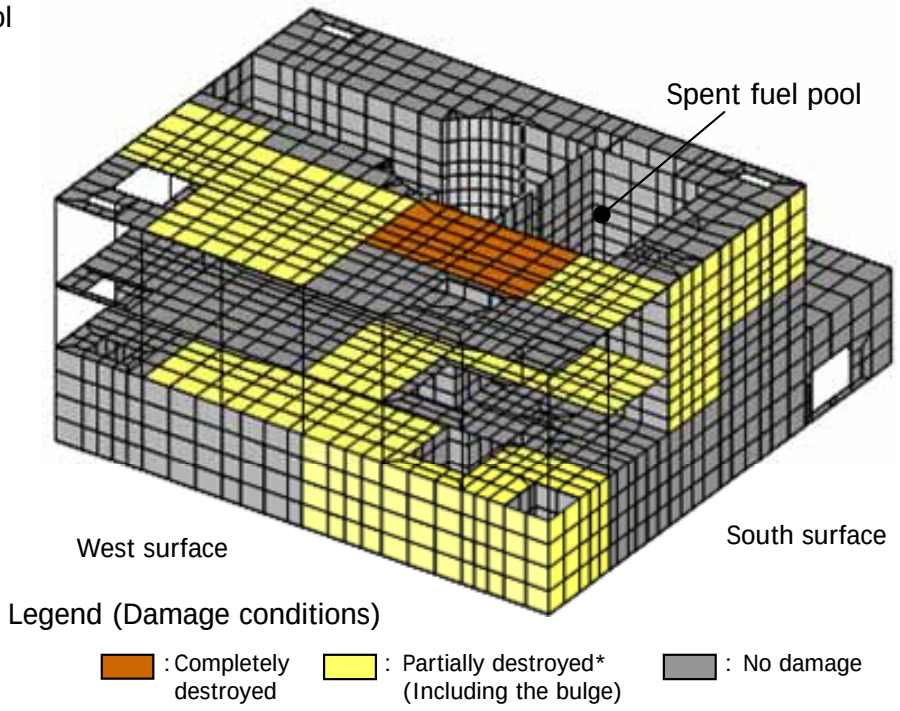


4. Seismic Resistance Evaluation under Assumption of Spent Fuel Removal

- Under assumption of spent fuel removal which is scheduled to start at the end of next year, a computer analysis was done to evaluate the seismic resistance of the reactor building and the spent fuel pool.
- The analysis was done under assumption (conditions allowing for spent fuel removal) that all the debris is removed from the upper part of the reactor building and equipments such as the fuel handling machine and its support structure are installed. The weight change of the reactor building and the current damage conditions were taken into consideration in the analysis. The support structure for the crane (See page 18) was not included in the weight placed on the reactor building.



Assumed conditions of the reactor building

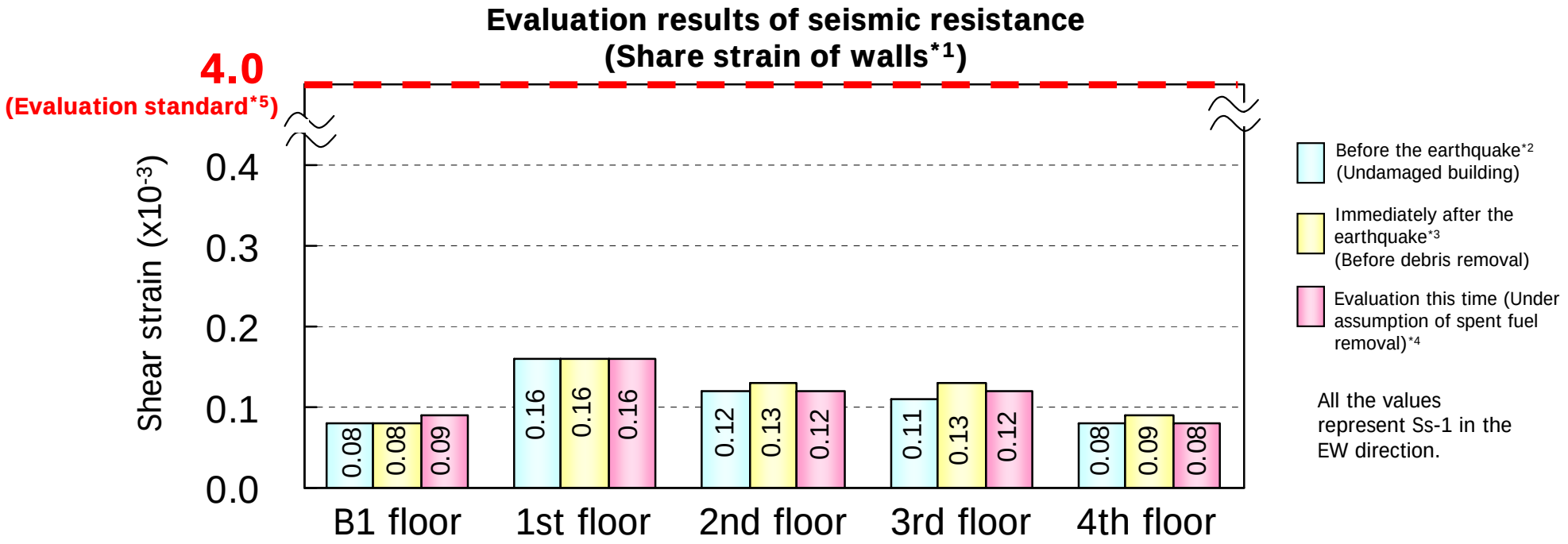


Computer analysis model
(in consideration of damage conditions)

* Only takes into considerations the wall weight (the wall rigidity not taken into consideration).

5. Sufficient Seismic Resistance of the Reactor Building

- The reactor building has seismic resistance equivalent to that of before the earthquake.
- The reasons supporting this result are as follows.
  (1) Debris removal will substantially reduce the weight of the upper part of the building which in turn will reduce the seismic force.
  (2) The spent fuel pool walls and the thick walls around the PCV remained intact even after the earthquake.



*1 Shear strain: Deformation caused by the force applied to the direction parallel to the internal face of the object

*2 Interim report (revision 2) on the seismic resistance evaluation results in accordance with the revised "Regulatory Guide for Reviewing Seismic Design of Power Generating Nuclear Facilities" (April 2010)

*3 "Report on the Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi Nuclear Power Station (1)" (May 28, 2011)

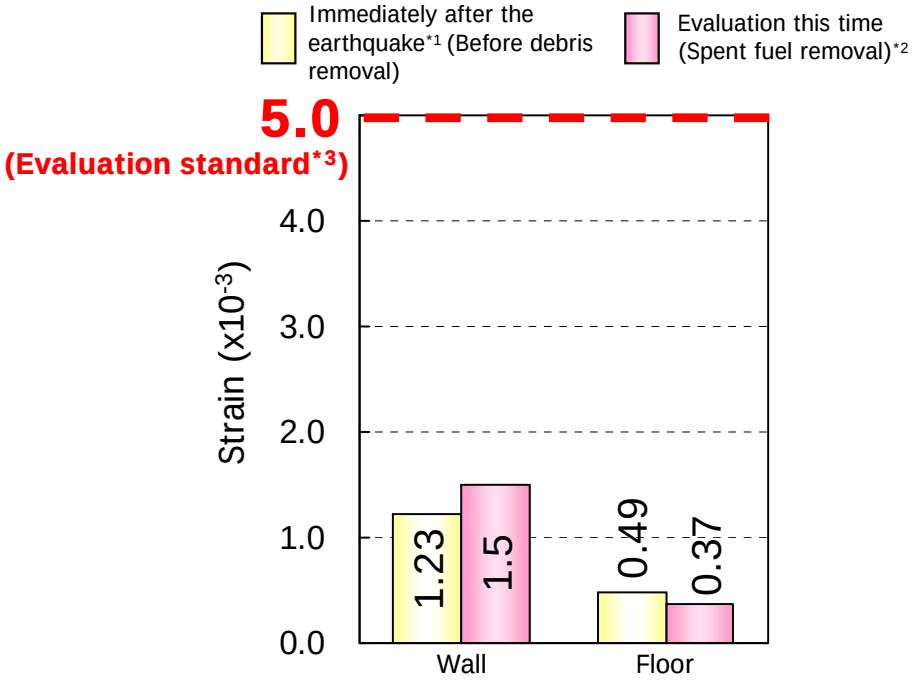
*4 "Report on the Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi Nuclear Power Station (1) (Supplement)" (August 30, 2012)

*5 The evaluation standard was set according to "JEAG 4601-1991: Technical guidelines for seismic design of nuclear power plants" (Japan Electric Association).

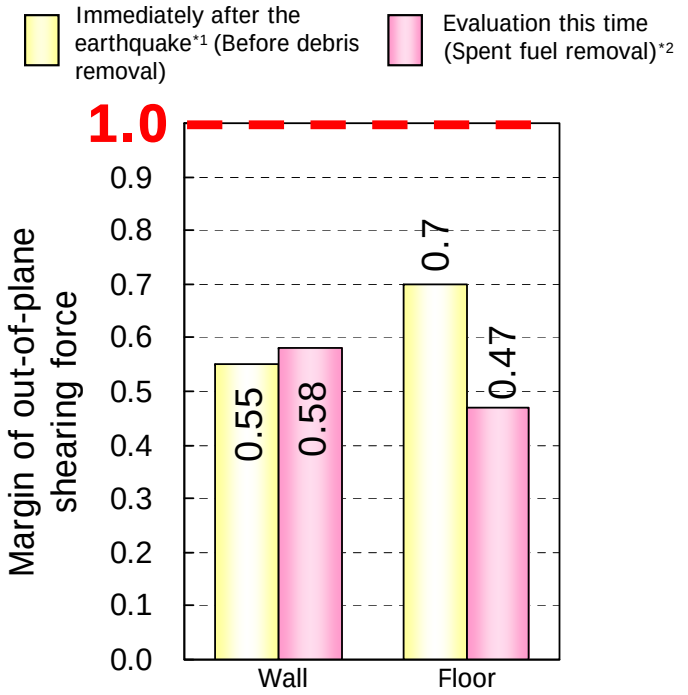
6. Sufficient Seismic Resistance of the Spent Fuel Pool (1)

- The strains and stresses generated in the spent fuel pool structure are lower than the evaluation standards, and thus, the pool has sufficient seismic resistance.

- Since the strains and stresses generated in the pool structure are sufficiently low, it has been judged that there is no possibility of the stainless-steel lining (of about 6mm thick) on the inner surface of the pool being damaged and water leaking from the pool. (See Reference 2 for details.)



Evaluation results of rebar tensile strain



Evaluation result of out-of-plane shearing force*4 (margin*5)

*1: "Report on the Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi Nuclear Power Station (1)" (May 28, 2011)

*2: "Report on the Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi Nuclear Power Station (1) (Supplement)" (August 30, 2012)

*3: The evaluation standards were set according to the "Standards for Power Generating Nuclear Facilities: Standards for Concrete Primary Containment Vessels" (Japan Society of Mechanical Engineers).

*4: Out-of-plane shearing force: Force that generates a shift towards the direction that the wall or floor is pressed.

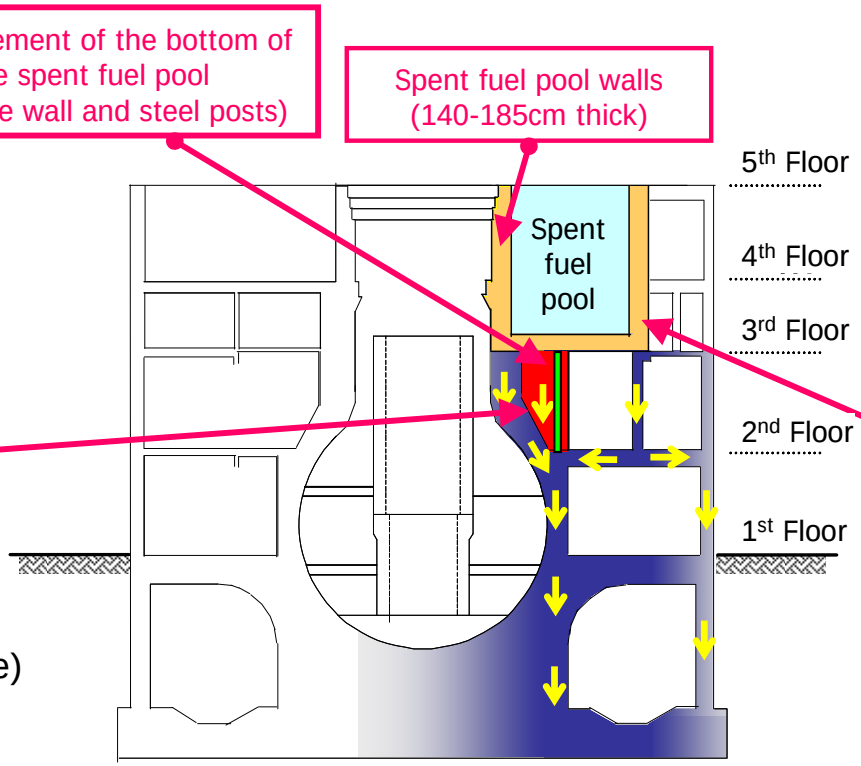
*5: Margin: Obtained by dividing the generated shearing force by the shear strength.

6. Sufficient Seismic Resistance of the Spent Fuel Pool (2)

- Since the spent fuel pool walls*1 are very thick and the pool is entirely supported by very thick walls*2, the seismic resistance equivalent to that of before the earthquake is maintained even with the exterior walls and the floor slabs of the reactor building being damaged. Therefore it has been confirmed that the spent fuel pool has a sufficient safety margin even in the case of a big earthquake equivalent to the Tohoku-Chihou-Taiheiyou-Oki Earthquake (JMA Seismic Intensity Scale 6+) in the future.

*1: Spent fuel pool walls: Reinforced concrete (Thickness: 140-185cm)
*2: Walls supporting the spent fuel pool: Reinforced concrete (Thickness: 160-185 cm)

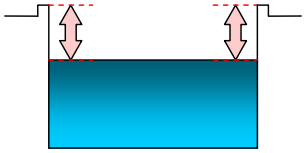
Wall supporting the pool (No damage)
(Before placement of concrete wall)
(Thickness: Approx. 160-185cm)



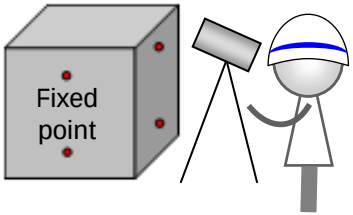
Spent fuel pool wall (No damage)
(Thickness: Approx. 140-185cm)

7. Regular Inspection of the Reactor Building and the Spent Fuel Pool

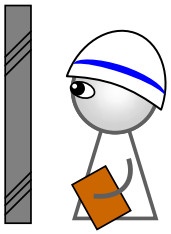
- Regular inspection will be conducted four times a year to confirm the soundness of the reactor building and the spent fuel pool.
- The first inspection was conducted from May 17 to 25, 2012 and the second inspection was done from August 20 to 28, 2012. No problem was found with the reactor building and the spent fuel pool as a result of these inspections (See Reference 3 for the outline of the inspection results).



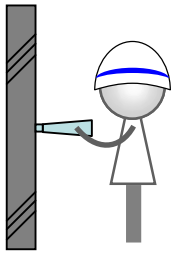
(1) Building tilt measurement (Water level measurement)



(2) Exterior wall measurement



(3) Visual inspection



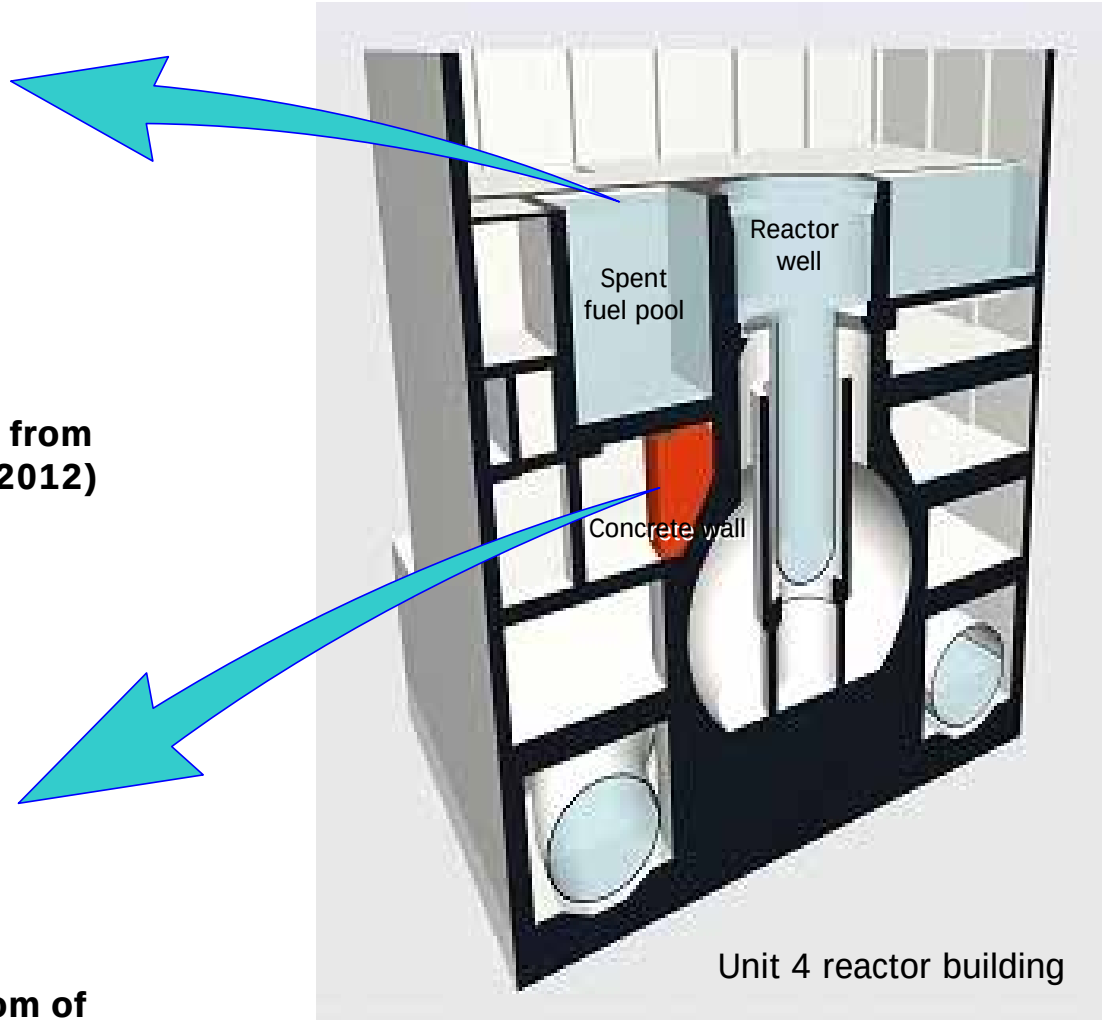
(4) Concrete strength measurement

8. Government Officials' Visits to the Power Station

- Government officials such as Mr. Nakatsuka, senior vice minister of the Cabinet Office (April 23, 2012) and Mr. Hosono, Minister of State for the Nuclear Power Policy and Administration (May 26, 2012) visited the power station to observe Unit 4 reactor building.

Observing the entire view of the spent fuel pool from the platform installed on the 5th floor (May 26, 2012)

Observing the reinforcement added to the bottom of the spent fuel pool on the 2nd floor (April 23, 2012)

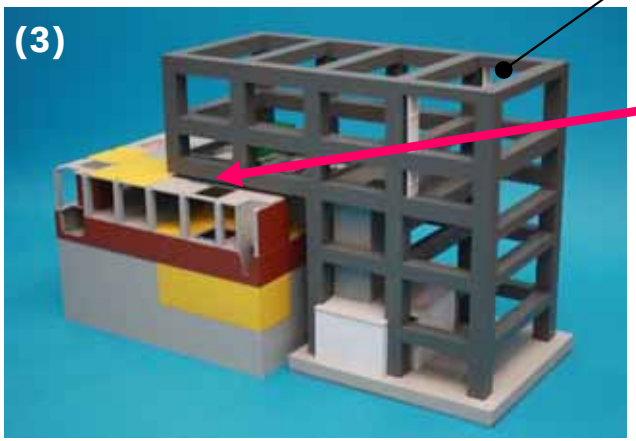


9. Cover Installation for Spent Fuel Removal

- Cover installation for spent fuel removal will be done for the purposes such as to support the fuel handling machine, provide a safe working environment and prevent radioactive materials (generated from spent fuel removal) from being scattered and spread.
- The installation was started on April 17, 2012 and foundation work is currently ongoing.

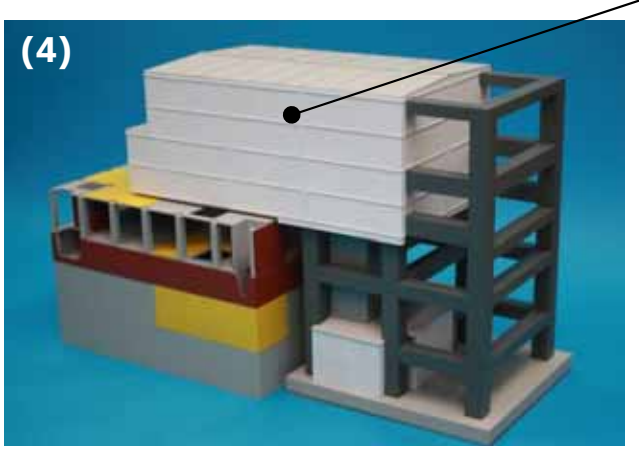
Completion of debris removal (Scheduled to be completed in October 2012)

Installation of fuel handling machine support structure



Installation of crane support structure

The weight of the crane support platform is not applied to the reactor building.

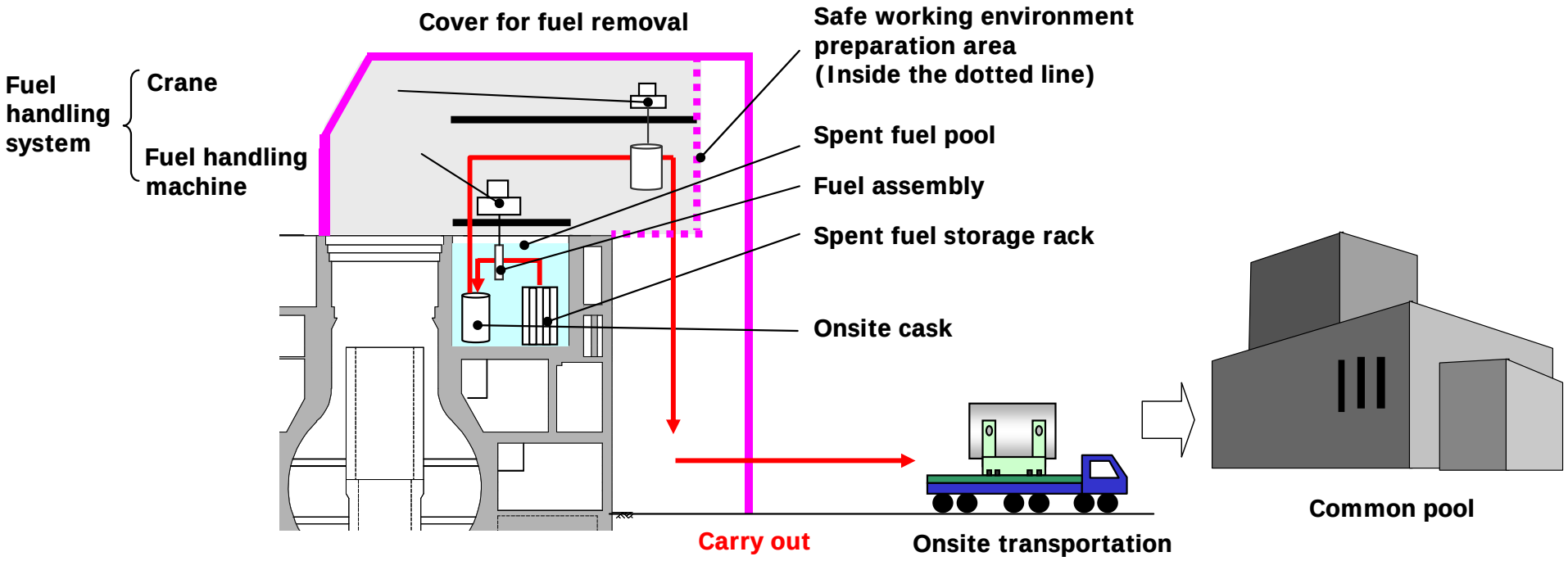


Installation of roof and exterior walls

As these models represent the overview of the building structure, the actual structure may be different.

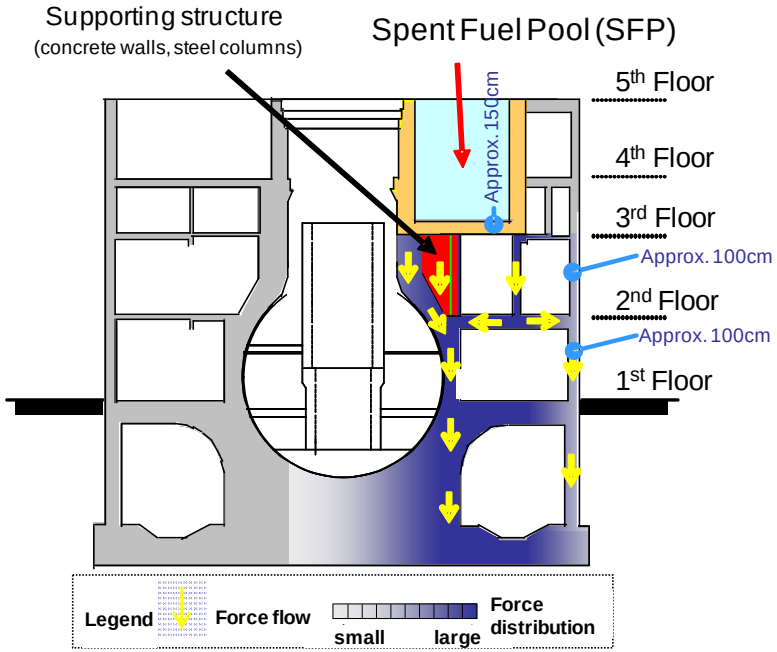
10. Progress towards Spent Fuel Removal

- After the cover installation for fuel removal, the fuel in the spent fuel pool will be inspected and moved to the common pool utilizing casks for more stable storage conditions. The spent fuel removal will be started in 2013.

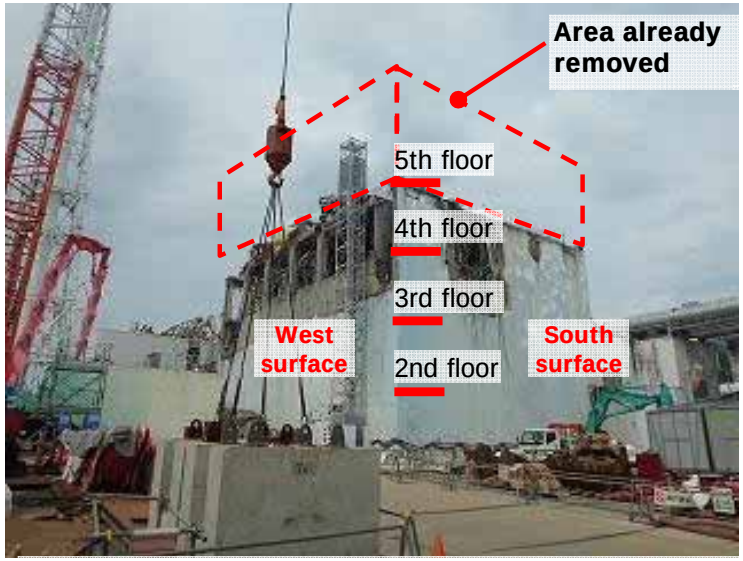


Fuel removal from the spent fuel pool

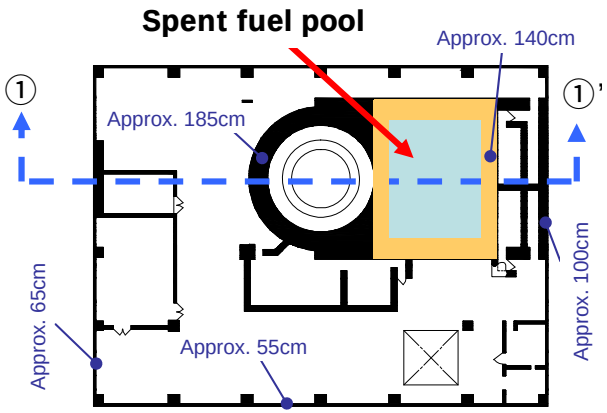
Reference 1: Positional relationship between the spent fuel pool structure and its support structure



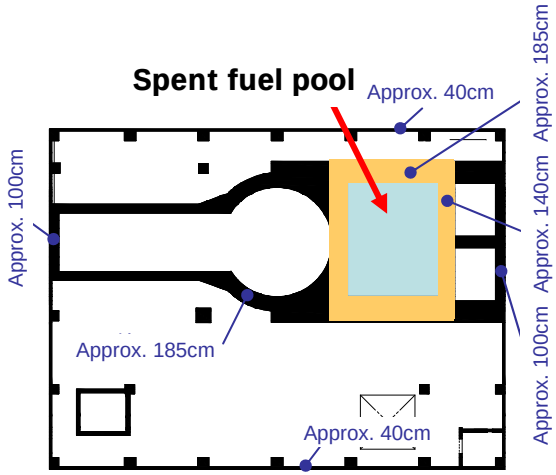
Flow and distribution of force in the spent fuel pool (Section ①-①' of the reactor building)



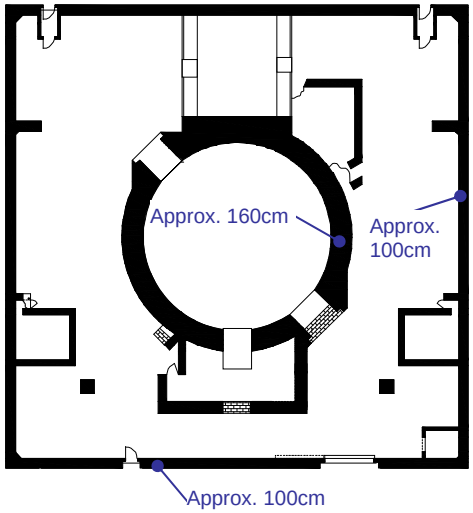
South and west surfaces of the reactor building (photographed on July 5, 2012)



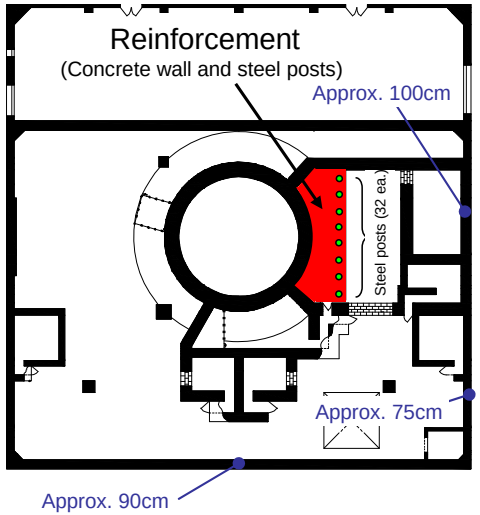
3rd floor - Plan view



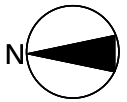
4th floor - Plan view



1st floor - Plan view



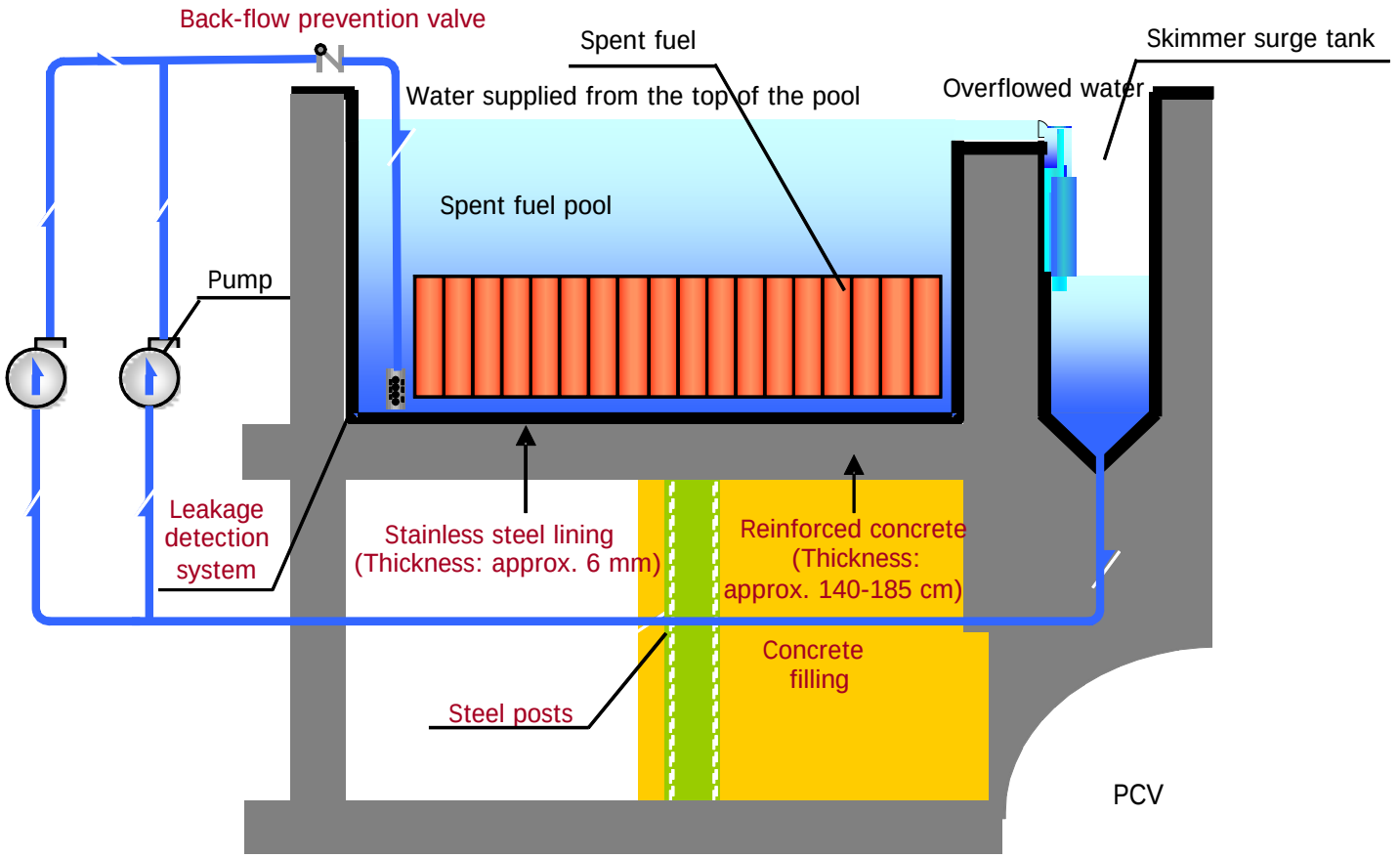
2nd floor - Plan view



Reference 2: The structure of the spent fuel pool allows for no leakage (1)

- The inner surface of the pool is covered with a stainless-steel lining.
  - The spent fuel pool is made of reinforced concrete which is about 140-185cm thick. In addition, the inner surface of the pool is covered with a stainless-steel lining of about 6mm thick.
- There are no pipes or drain holes penetrating through the side walls and the bottom of the spent fuel pool.
  - The water circulating in the pool is injected from the top of the pool, and the overflowed water flows into the skimmer surge tank. There are no pipes or drain holes penetrating through the side walls and the bottom of the spent fuel pool which may be of risk for water leakage.
- Water leakage from the spent fuel pool is being monitored.
  - The water level of the skimmer surge tank[*1] is monitored at all times and the amount of water evaporated from the pool surface is supplied as necessary. In the event of water leakage due to pipe damage, etc., the leakage can be detected as an abnormal decrease of the skimmer surge tank water level.
- The water injection pipe is designed to prevent back-flow of pool water.
  - A back-flow prevention valve requiring no power is installed in the pipe that feeds water to the pool. Even in the case that the pipe is damaged, back-flow of pool water can be prevented as the valve closes.

Reference 2: The structure of the spent fuel pool allows for no leakage (2)



Structure of the spent fuel pool

*1: Skimmer surge tank is a vessel that receives the overflowed water from the spent fuel pool.

Reference 3: Outline of the second inspection results (1)

- Inspection period
  August 20-28, 2012
- Results

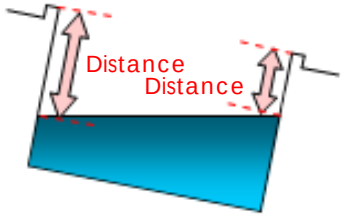
(1) Building tilt measurement (Water level measurement)

Since the water levels measured at the four corners of the pool were about the same as those measured before, it has been judged that the 5th floor surface, the spent fuel pool water surface and the reactor well water surface are parallel and therefore the building is not tilted.

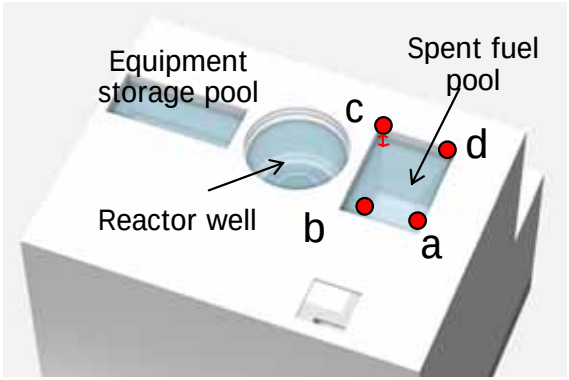
1) Building not tilted

The distances are about the same

2) Building tilted



The distances are different



Measurement points (Floor surface of the 5th floor)

Water level *1 measurement results

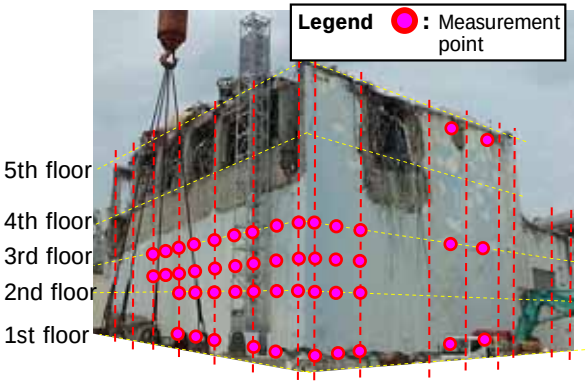
Unit: mm

Spent fuel pool	August 21, 2012 (Latest measurement)
a	453
b	453
c	452
d	452

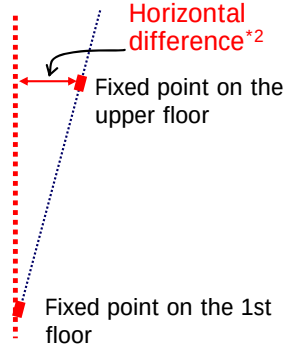
*1 Water levels may change daily depending on the operation status of the cooling system.

(2) Exterior wall measurement

The horizontal difference*2 measured this time was about the same as those measured in the first regular inspection (May 2012) and the detailed exterior wall inspection (June 2012), and the deformation found at each measurement point has a similar tendency. For the south and west exterior walls of the 2nd floor where partial bulge was found, the analysis was done without taking into considerations the wall rigidity. The results indicate no problem with the seismic safety of the reactor building.*3



Measurement points



*2 Horizontal distance between the fixed point on the 1st floor and the fixed point on the upper floor

*3 "Report on the Seismic Safety of Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station in Consideration of the Partial Bulge on the Exterior Walls" (June 25, 2012)

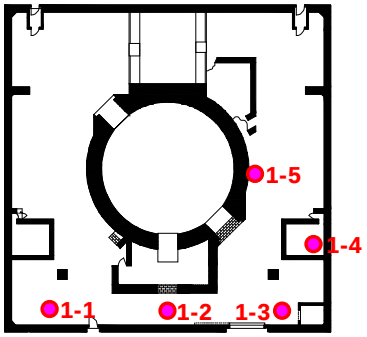
Reference 3: Outline of the second inspection results (2)

(3) Visual inspection

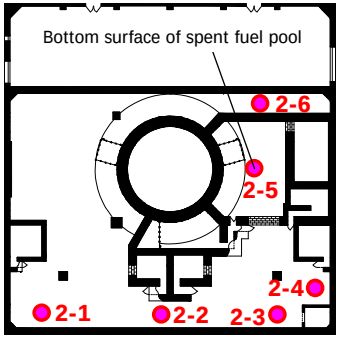
Similarly to the previous inspection, we found no cracks of a width of 1mm or more (which requires a durability study) or of risk for rebar corrosion due to being exposed to salt as a result of visually inspecting the spent fuel pool walls/floor and the walls supporting the pool.

(4) Concrete strength measurement

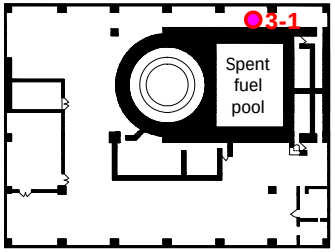
As the concrete strengths at all the measurement points were higher than the design basis strength (22.1 N/mm^2) similarly to the previous inspection, it can be concluded that the building has a sufficient structural strength.



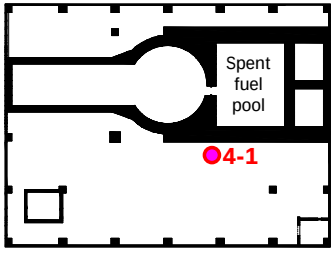
1st floor - Plan view



2nd floor - Plan view

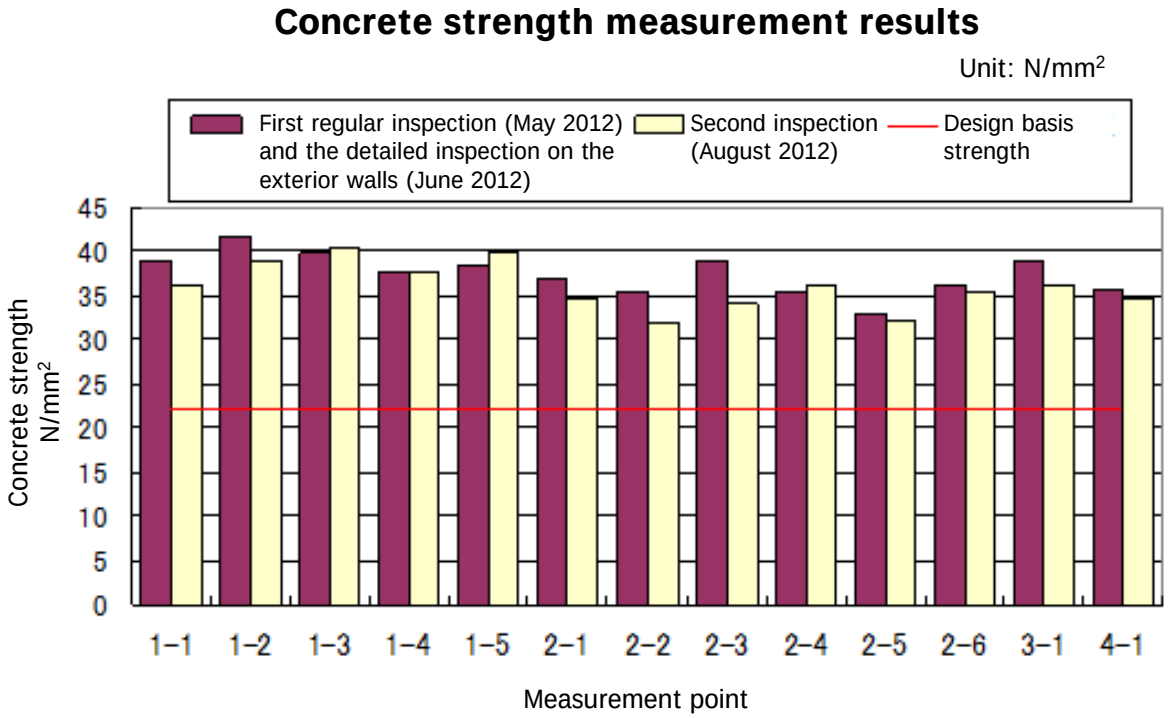


3rd floor - Plan view



4th floor - Plan view

Legend: Measurement point



Reference 4: Related Documents and Links

- Submission of the report on the current seismic resistance and reinforcement of the reactor buildings at Fukushima Daiichi Nuclear Power Station (1) (May 28, 2011)
  http://www.tepco.co.jp/cc/press/11052801-j.html
- Completion of Support Structure Installation under the Bottom of the Spent Fuel Pool in Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station (July 30, 2011)
  http://www.tepco.co.jp/nu/fukushima-np/images/handouts_110730_02-j.pdf
- Overview plan of cover installation for fuel removal at Unit 4 of Fukushima Daiichi Nuclear Power Station (April 16, 2012)
  http://www.tepco.co.jp/cc/press/2012/1201925_1834.html
- We affirm that Unit 4 reactor building and the spent fuel pool will not collapse in the event of an earthquake (April 26, 2012)
  http://www.tepco.co.jp/nu/fukushima-np/info/index-j.html
- Soundness Verification Results of Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station (May 25, 2012)
  http://www.tepco.co.jp/nu/fukushima-np/images/handouts_120525_07-j.pdf
- Report on the Results of Seismic Safety Evaluation of Unit 4 at Fukushima Daiichi Nuclear Power Station to the Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (June 25, 2012)
  http://www.tepco.co.jp/cc/press/2012/1205832_1834.html
- Completion of debris removal from the upper part of Unit 4 reactor building at Fukushima Daiichi Nuclear Power Station Unit 4 (July 11, 2012)
  http://www.tepco.co.jp/nu/fukushima-np/images/handouts_120711_01-j.pdf
- Report on the Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi Nuclear Power Station to the Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (1) (Supplement) (August 30, 2012)
  http://www.tepco.co.jp/cc/press/2012/1217264_1834.html
- Results of the Second Soundness Inspection of Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station (August 30, 2012)