Brief Review of Building Damage by The 2011 Tohoku Japan Earthquake and Following Activities for Disaster Mitigation

Masanori Iiba*, Isao Nishiyama, Izuru Okawa, Hiroshi Fukuyama (BRI) and Yasuo Okuda (NILIM)

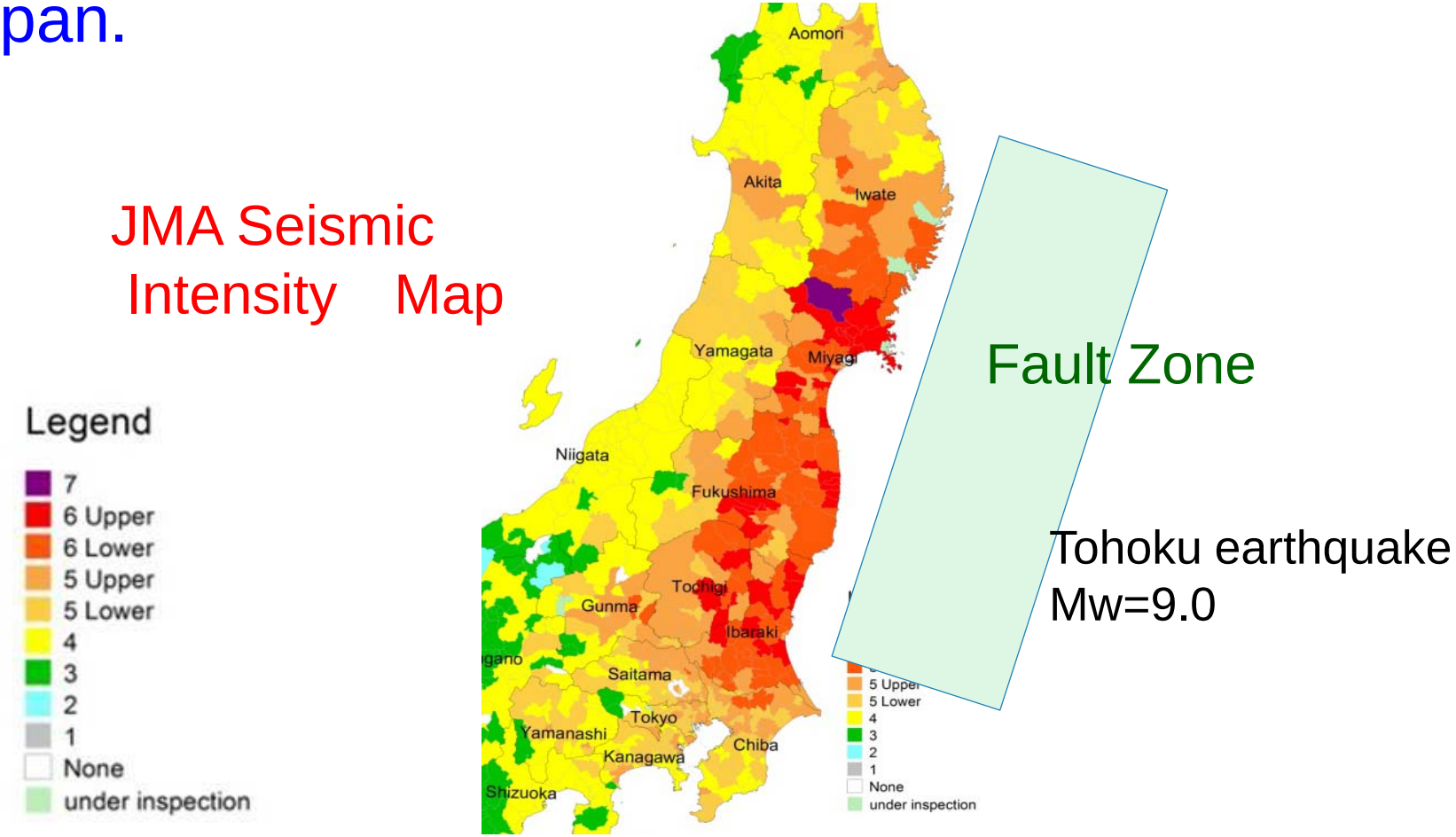
BRI : Building Research Institute
NILIM : National Institute for Land InfrastructureManagement

44th JOINT PANEL ON WIND AND SEISMIC EFFECTS, UJNR

*The 2011 Tohoku Japan earthquake of moment magnitude (Mw) 9.0 occurred at 14:46 JST on March 11, 2011

*Generated large ground motion and gigantic tsunami in Tohoku and Kanto areas of the northeastern part of Japan.

JMA Seismic Intensity Map



The BRI and the NILIM conducted field survey and summarized the reports. To reflect to practices such as the revision of building structural codes, the BRI and the NILIM are collaboratively carrying out coping activities with the help of the administration by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

CONTENTS

Brief review of the building damage is presented which is based on the research and reconnaissance reports.

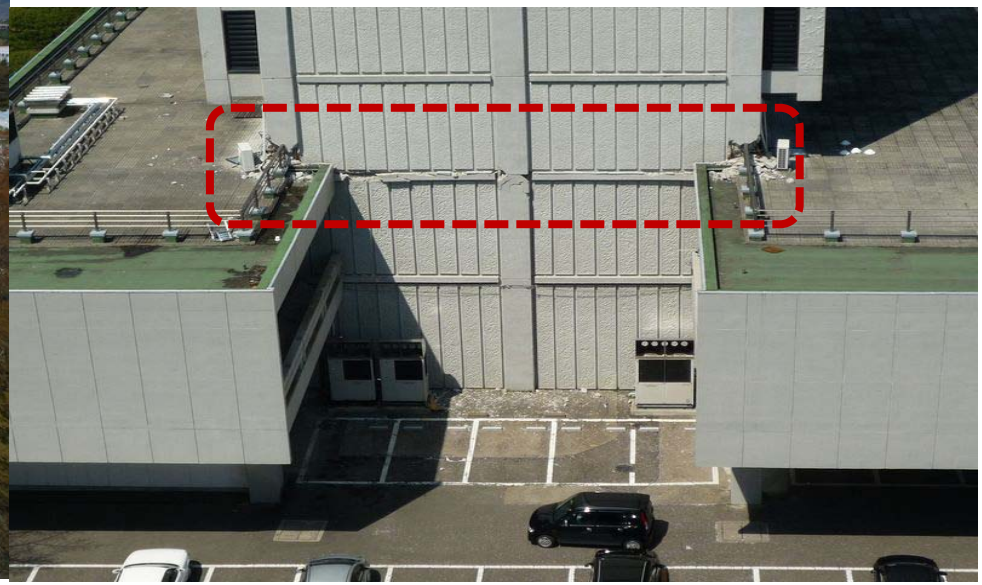
Several key issues to be coped with by the building structural codes are identified.

1) Long-duration and long-period earthquake ground motion for design use

2) Higher level of performance for keeping function after earthquake

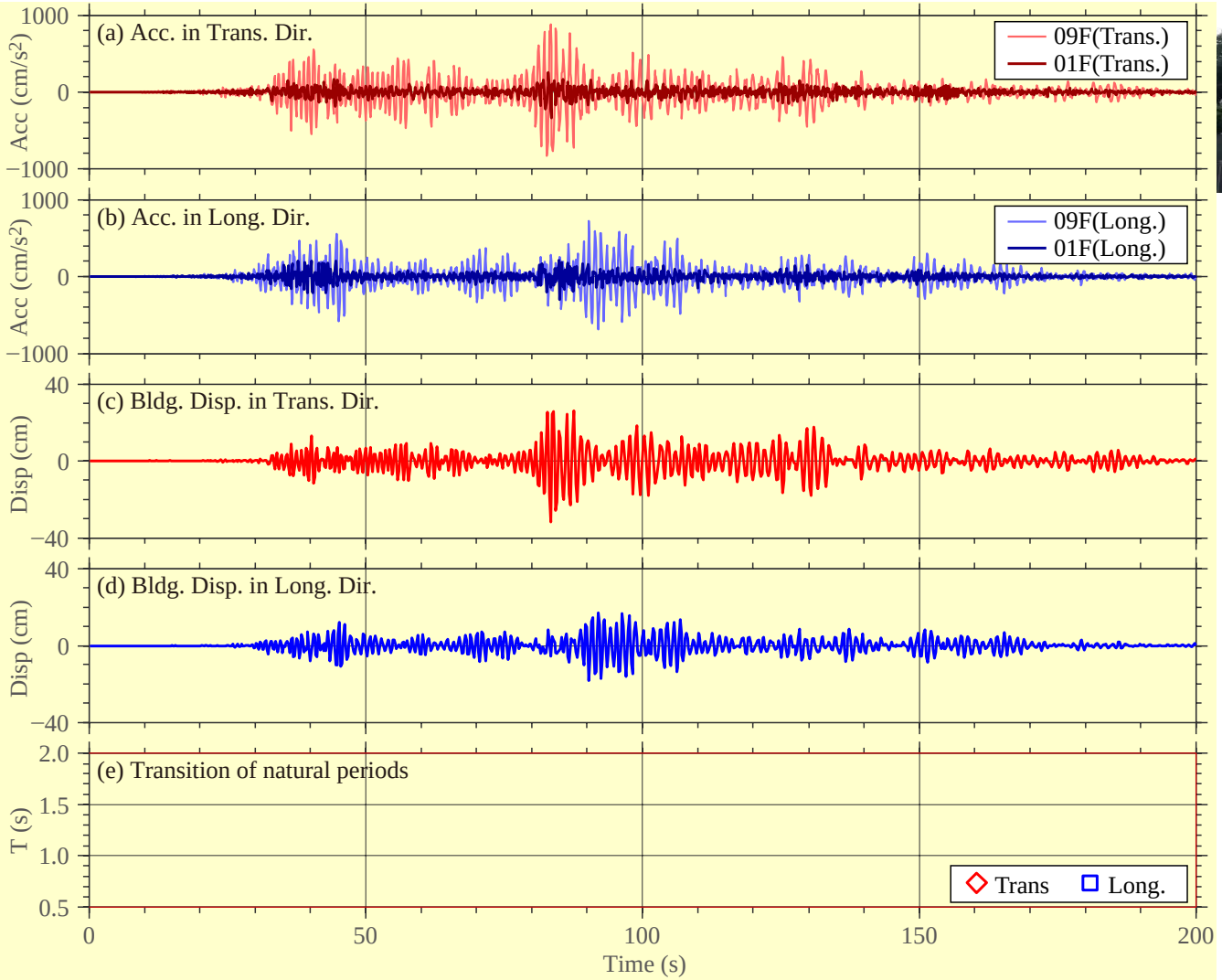
3) Detailed evaluation for earthquake resistance performance of building

Damaged Building in Sendai city



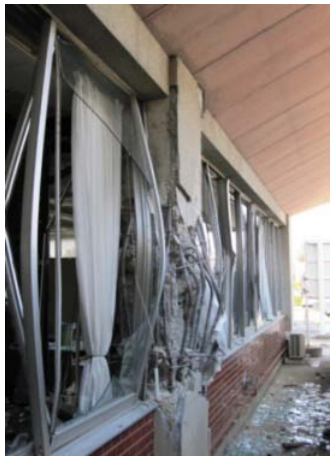
Flexural failure of multi-story shear walls which can absorb large earthquake energy was observed. Though the building could secure human lives, buckling and/or rupture of steel bars and steel plates in the columns and compressive crashing of concrete were observed.

BRI Strong Motion Network
EQ motions for Damaged Building



Earthquake Motion Damage

Earthquake Motion Damage (cont.)



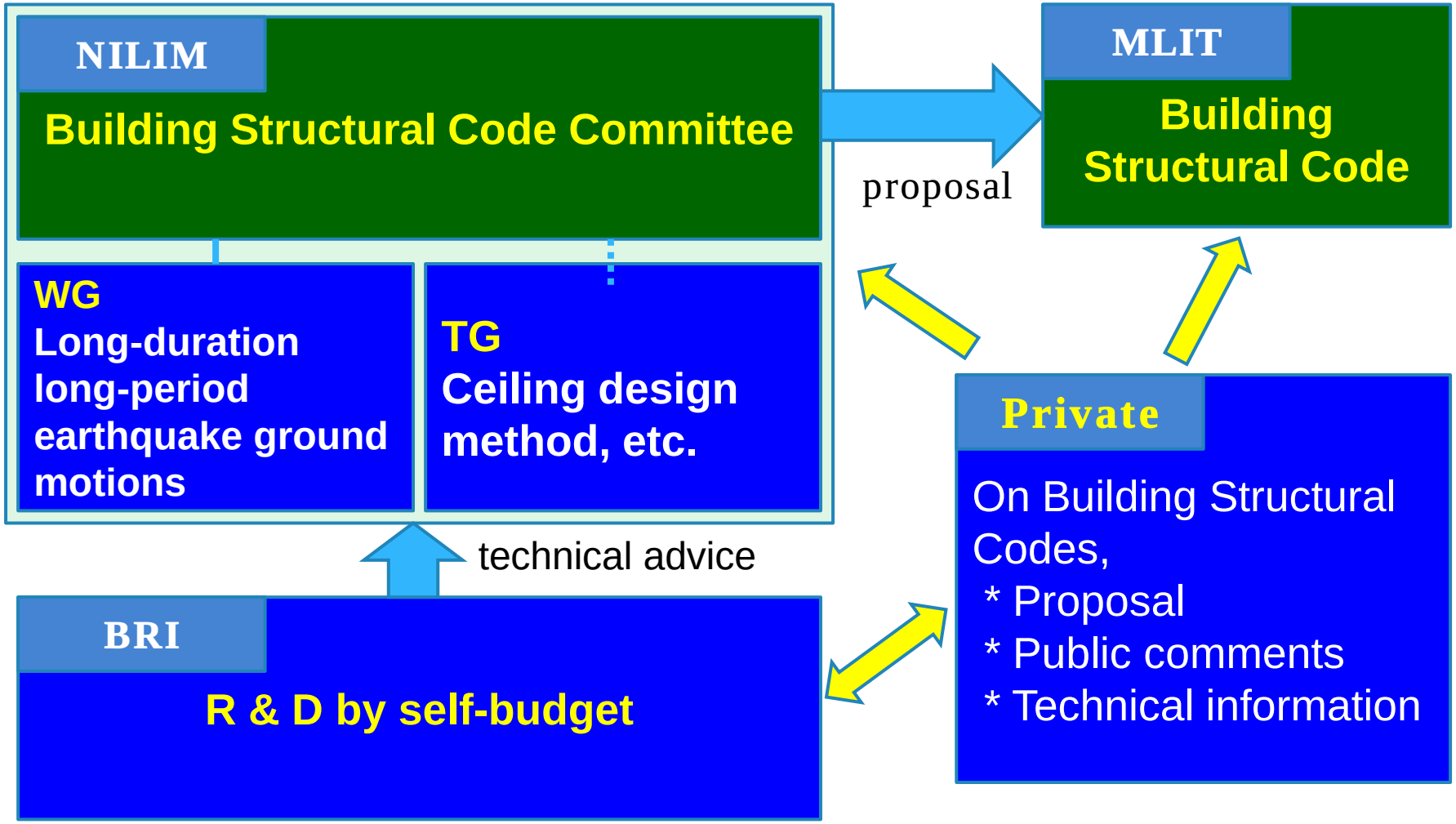
On-going Activities for Disaster Mitigation

1. Digital data analysis for BRI strong motion
2. Under long-duration and -period ground motion (multiple cycles) and structural performance
3. Fall down of ceilings and escalators
4. Inclination due to liquefaction in residential houses
5. Evaluation of tsunami force
6. etc.

In addition,

1. Higher level of performance for keeping function after earthquake
2. Detailed evaluation for earthquake resistance performance of building

System to Revise Building Structural Codes



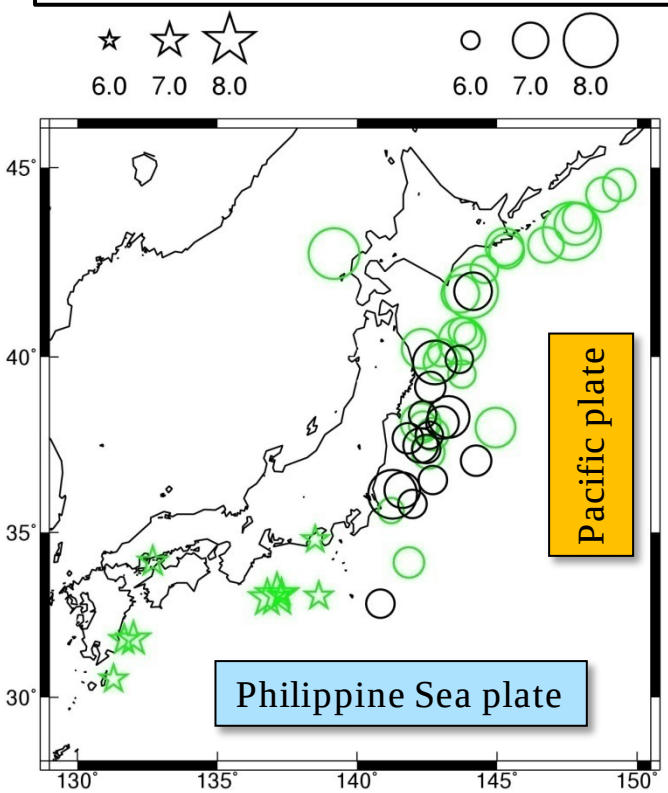
1) Evaluation method of Long-duration and long-period ground motion based on earthquake observed motions at about 1600 stations

ORIGINAL EVALUATION MODEL

MLIT PROPOSAL FOR DESIGN MOTION
CALL FOR PUBLIC COMMENTS, 2010

2011.3.11 Tohoku EQ.

Revision of the model



Earthquakes used in the analyses

Long-duration and long-period motion properties
- Spectral amplitudes from large earthquakes
- Duration of motions with each frequency band

- **earthquake magnitude**
- **distance**
- **site specific coefficients**

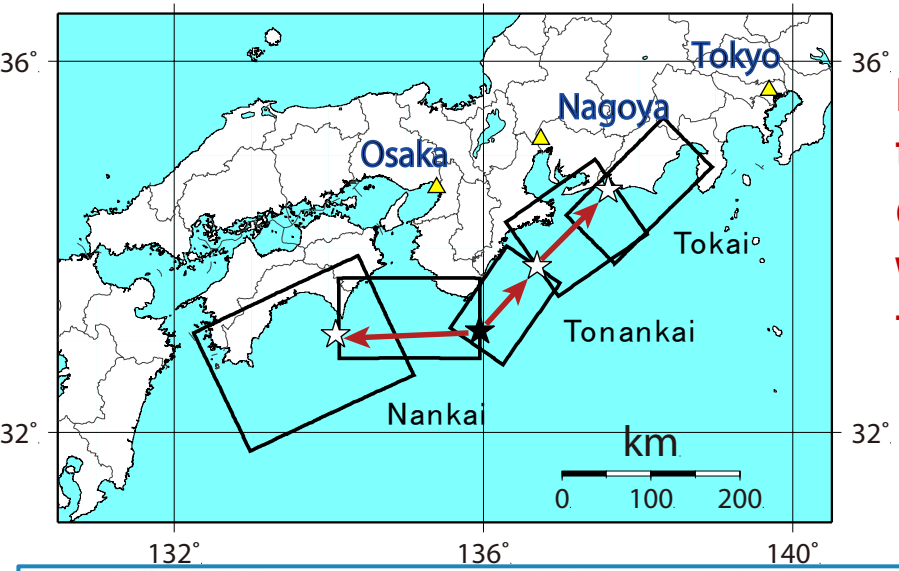
+ (additional factors)

- **Epicenters**
- **Paths**

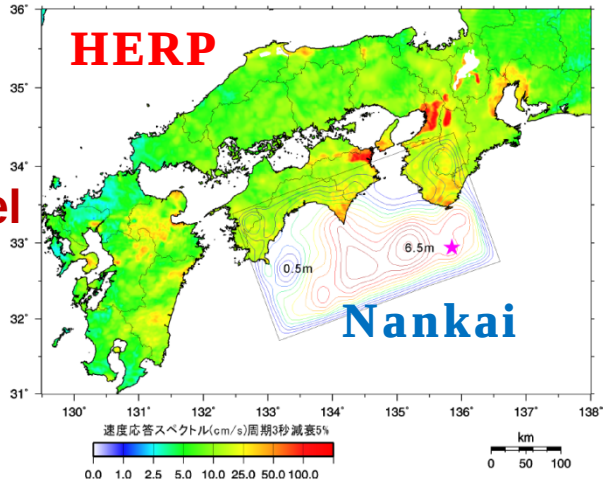
Revised evaluation method

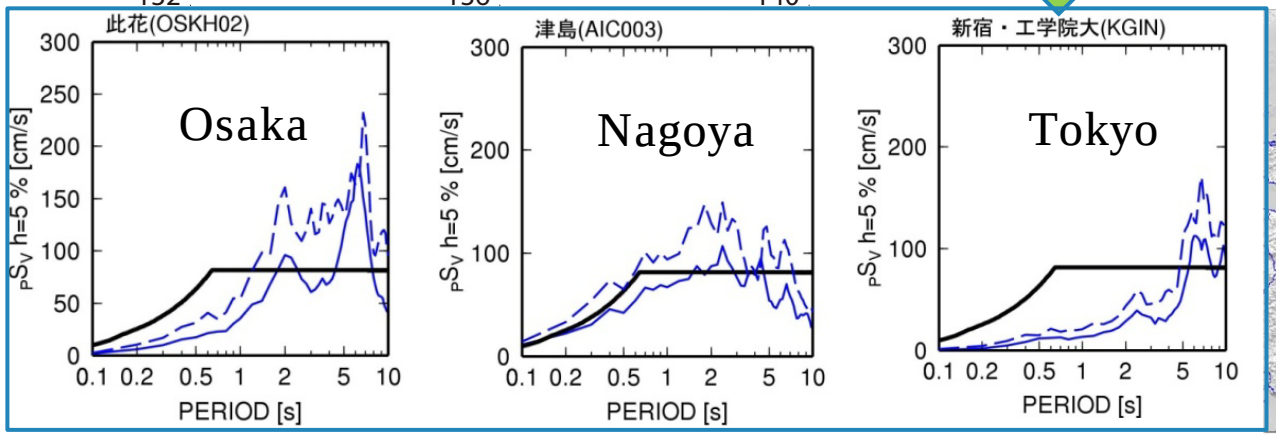
Evaluation method of Long-duration and long-period ground motion (cont.)

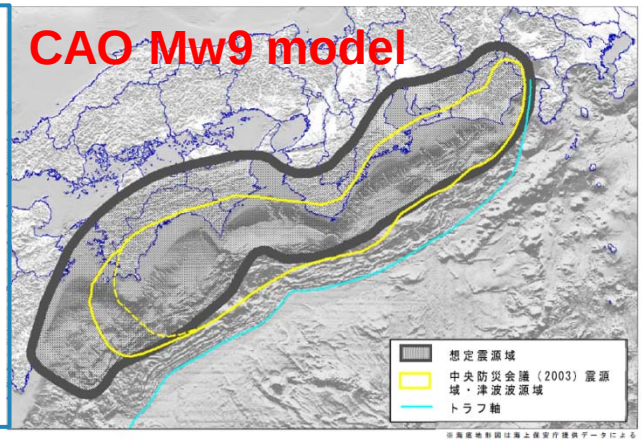
The motions were evaluated for major urban areas with three- (and four-) connected earthquakes, by HERP, CAO, AIJ, etc. The MLIT is going to propose a design long-duration and long-period motions to evaluate response of super high-rise buildings, etc..



Nankai-trough three-connected earthquake model with revised model for major areas

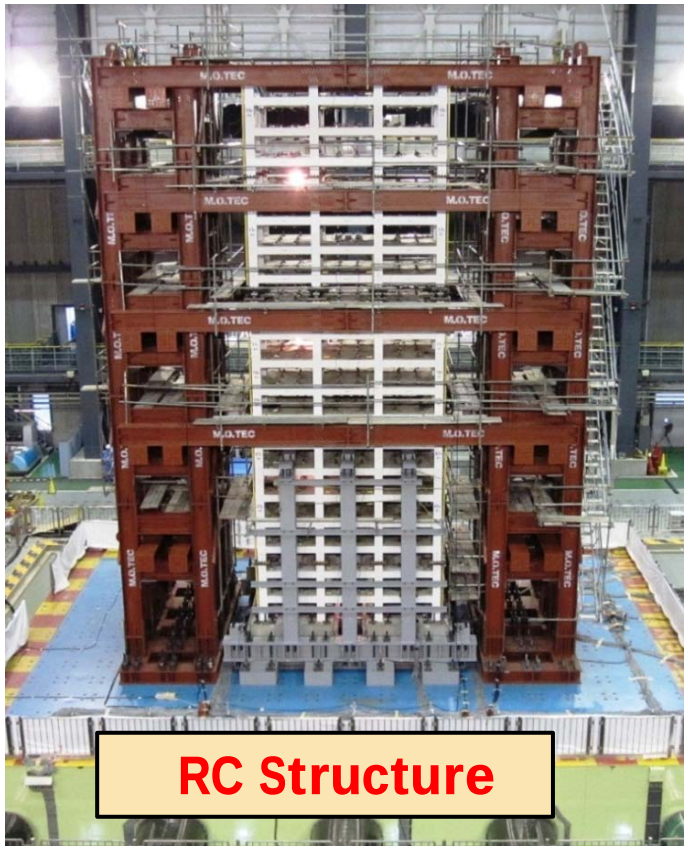


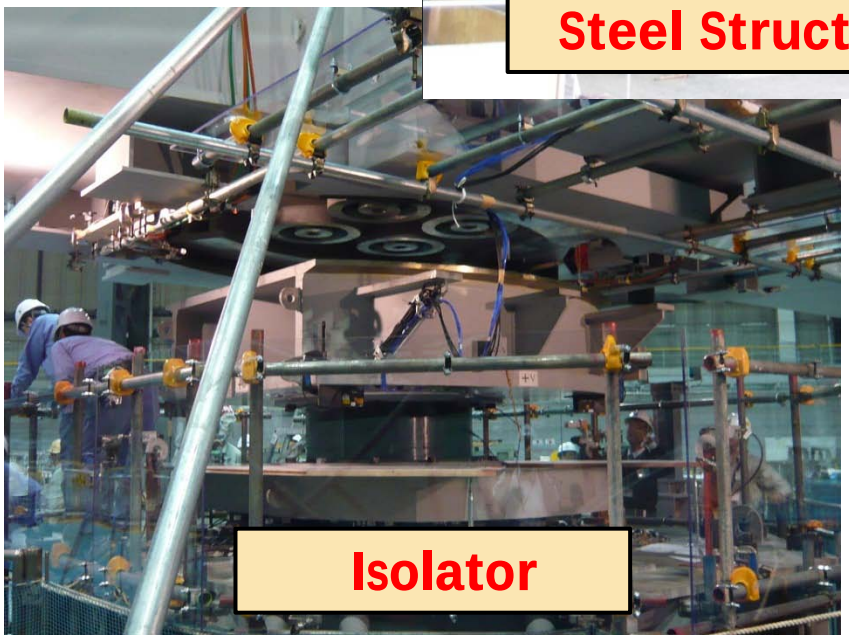




Structural performance against long-duration and long-period ground motions (full-scale test)

These large-size experiments are carried out under the research cooperation between the BRI and the institutions headed by Obayashi, Kajima and Taisei Co.





2) Higher Level of Performance for Keeping Function after Earthquake

National and local government office buildings must be an emergency base and assist refugees and citizens just after earthquakes. But more than 10 local government buildings suffered.

There were damages of structural and non-structural member. All of damaged buildings are designed by old building structural code, the judgment for safety or not depends greatly on the damage of non-structural members.

Another example is the damage of gymnasiums which must be utilized for places of refuge after earthquakes. A lot of gymnasiums suffered falling-down of ceiling and spall of concrete at joins between steel roofs and RC columns.

Because the damage on pile head of foundation, the super-structure tilted and the inhabitants could not continue to live in the building. The damage for buildings whose superstructure was retrofitted or strengthened was founded. These buildings will be demolished or jacked up after underpinning of foundation.

For performance for keeping functionality post earthquake, it must be avoid these damages for especially facilities as the emergency base and assist refugees and citizens such as national and local government office, gymnasiums, schools, residences and so on.

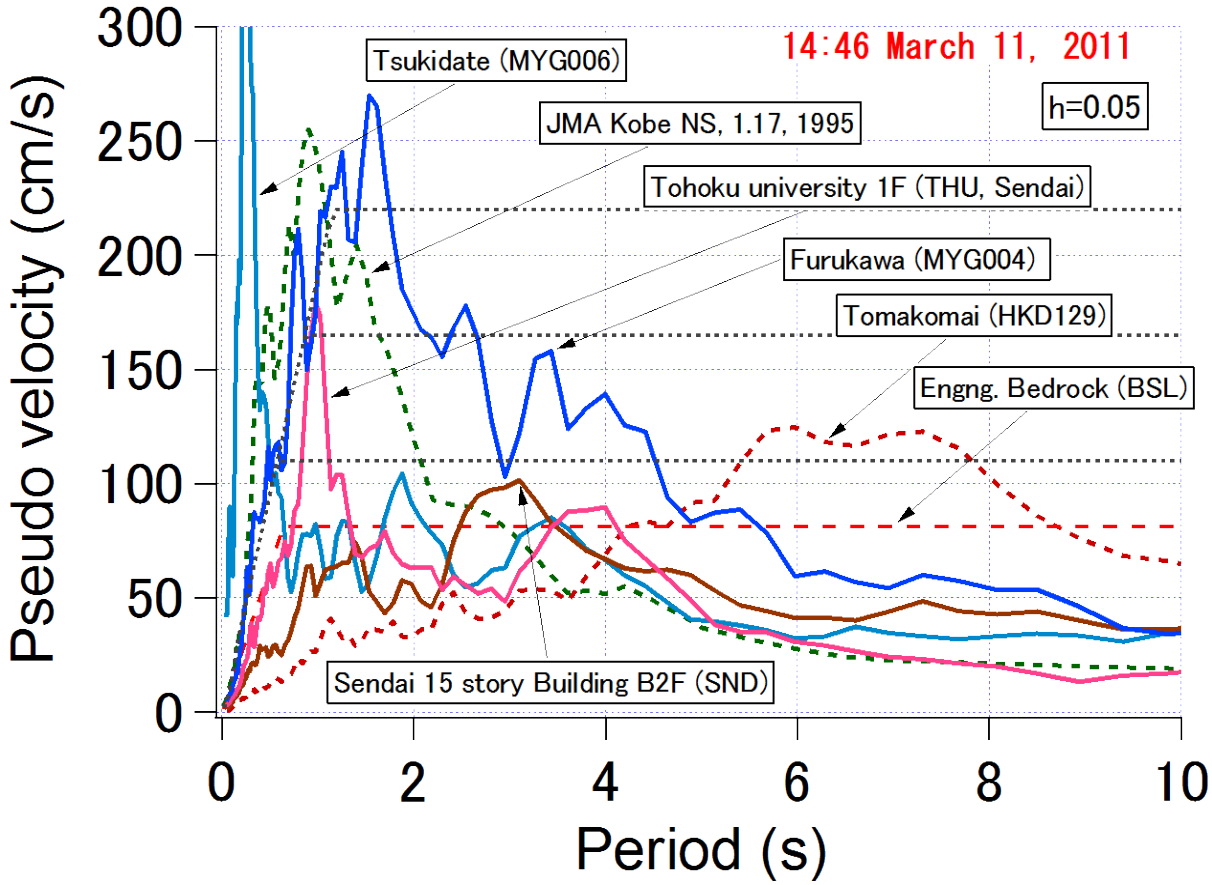
1) **The required performance for these buildings will be made clear to avoid these damages and**
2) **Technologies for an effective seismic retrofit will be developed.**

3) Detailed Evaluation for Earthquake Performance (response) of Building

On August 29, 2012, the estimation of earthquake damage by the mega-earthquake in Nankai trough was announced. In the worst case, the number of completely collapsed buildings and broken buildings by fire will be about 0.95 to 2.38 million and the number of lost people will be 80 to 320 thousands.

Earthquake motions observed during recent earthquakes sometimes exceeded the level in the code. But severe damages in the areas were not always reported.

Also under the mega-earthquake, earthquake motion will be severe and the amplitude will probably exceed the level of equivalent force prescribed in the building structural code.



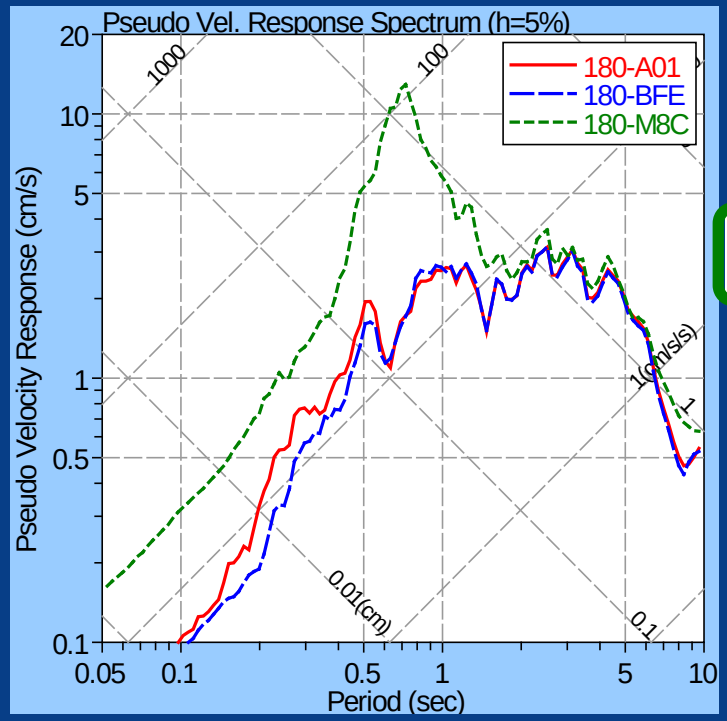
- **Example items which will be more precisely evaluated to predict the earthquake response and resistance of building**

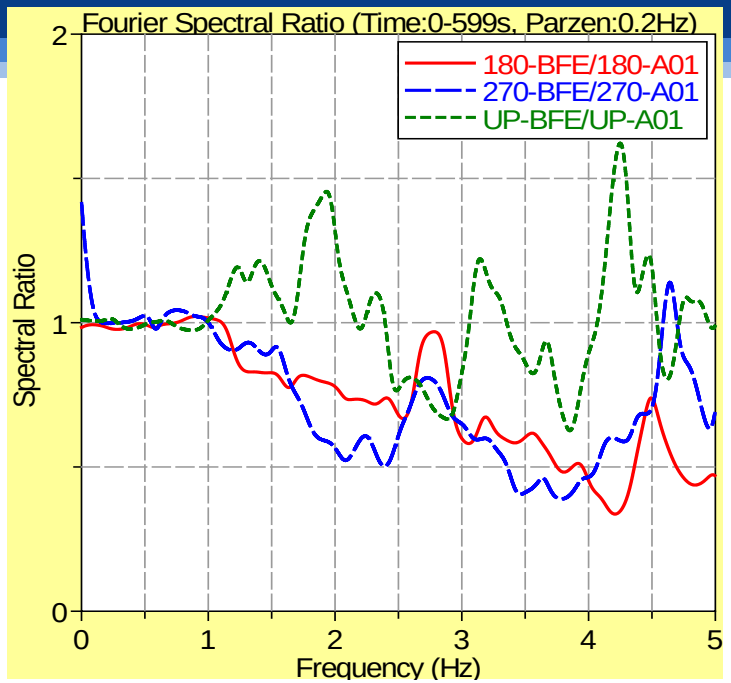
- **1) Dynamic soil structure interaction**
  Earthquake motions to building are changed by the kinematic interaction due to effects of embedment and pile foundation. Also the damping effects will be changed by radiation damping to ground through the foundation.

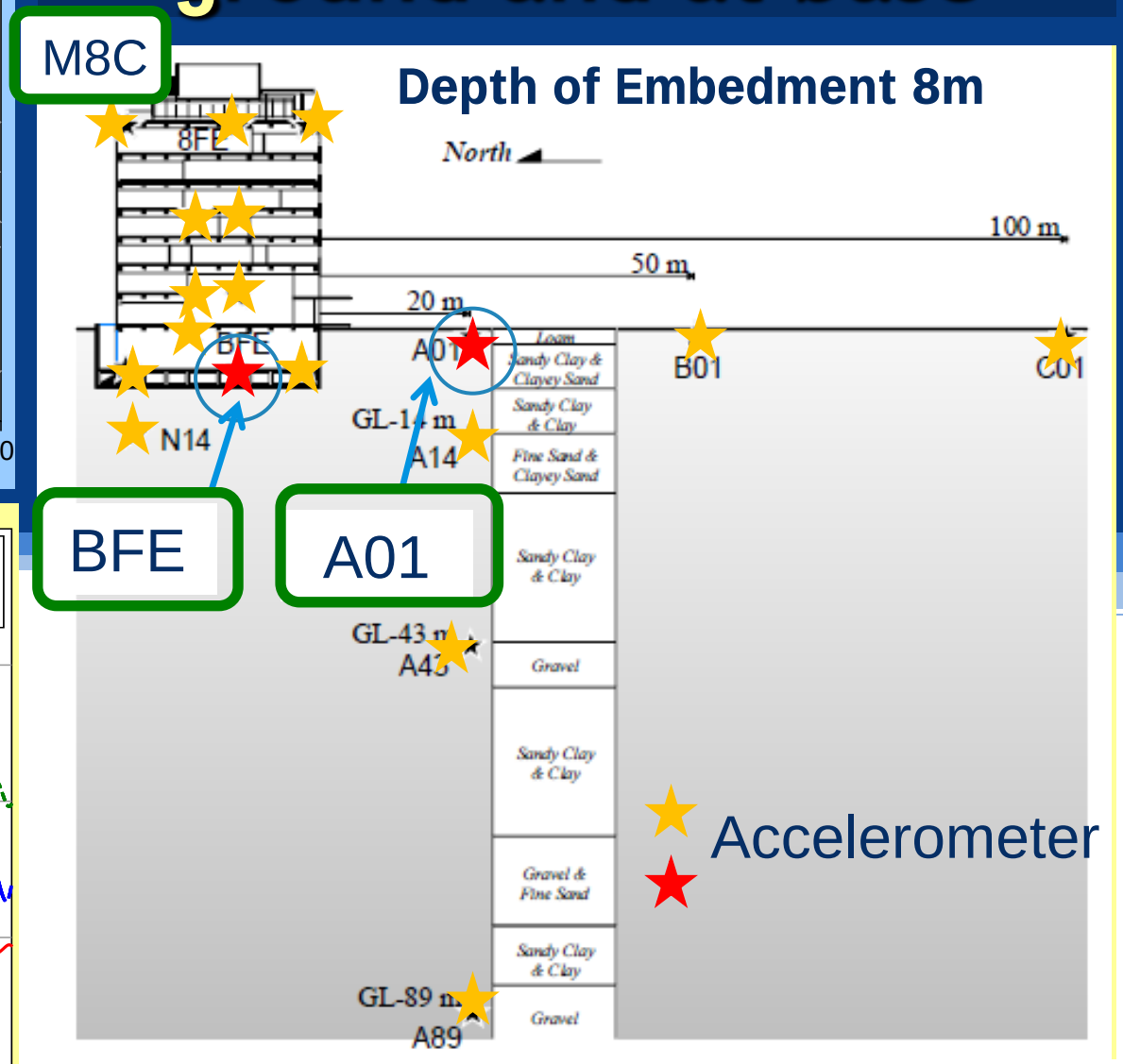
- **2) Structural modeling**
  More detailed modeling of structures is necessary to obtain the precise response of building. There are effects of presence of floor slab and restriction of column deformation on the response.

- **3) Material strength and proposed design formula**
  The design values of strength in every material and proposed design formula are set to a safety side. The values based on more actual characteristics must be estimated.

Input EQ motions on ground and at base







CONCLUSIONS

The BRI and the NILIM collaborated in the process of the recorded strong motions in and around instrumented buildings and also in the field survey of damaged buildings and residential land by the Tohoku Japan earthquake. The outlines of the on-going and near-future research activities for countermeasure against damages and so on are summarized.

- **1) Possibility of free access to the digital data recorded by the BRI strong motion network**
- **2) Prediction of long-duration and long-period earthquake ground motion for design use and re-evaluation of structural performance under multiple cycles of loadings**

CONCLUSIONS(cont.)

- 3) Improvement of the seismic performance of fallen down of ceilings and so on
- 4) Liquefaction prediction and countermeasure for residential houses
- 5) Evaluation of tsunami force necessary for the design of tsunami evacuation buildings
- 6) Higher level of performance for keeping function after earthquake
- 7) Detailed evaluation for earthquake resistance performance of buildings

Thank you for your kind attention.