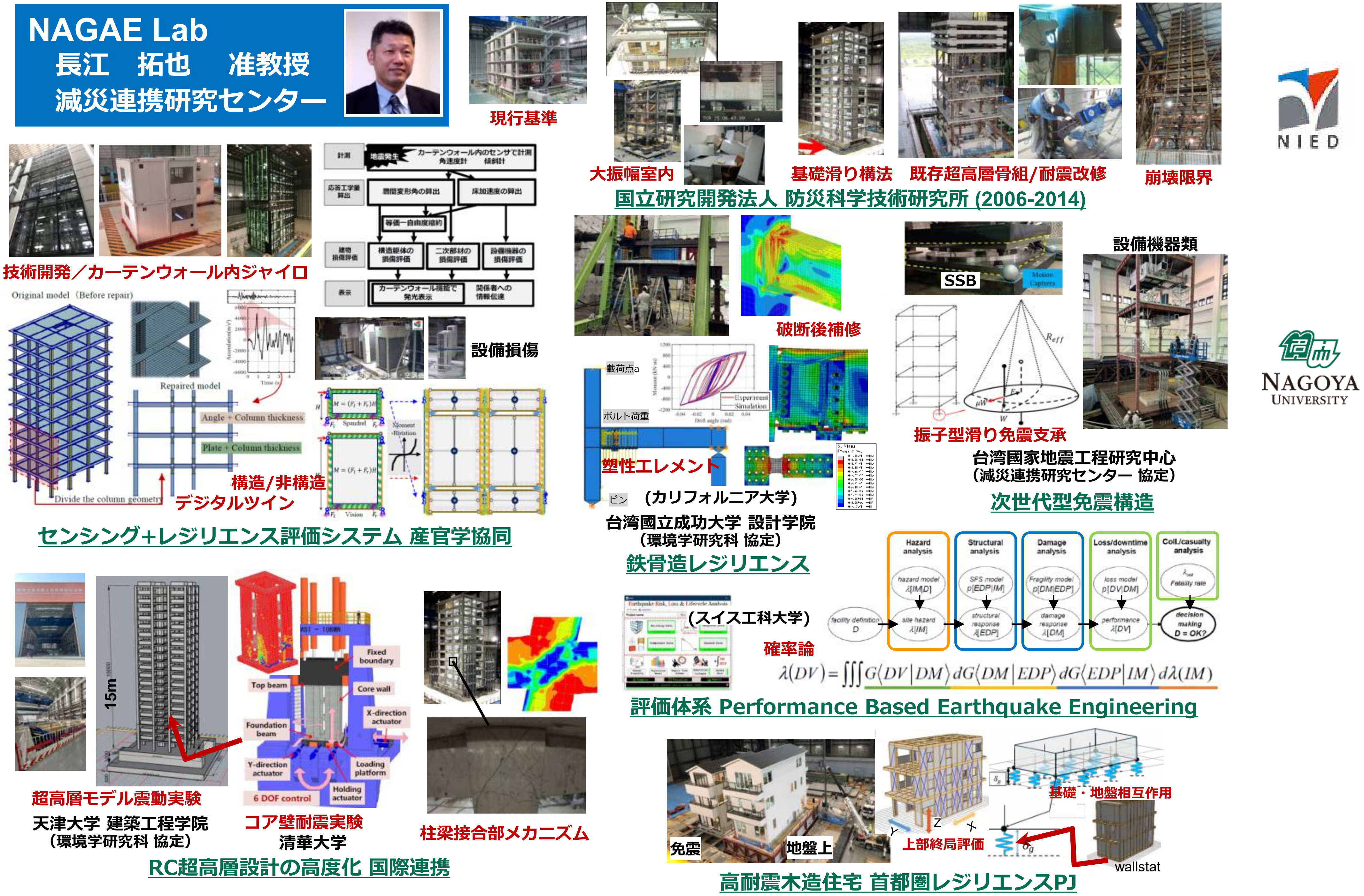
International Conference on Earthquake Engineering

CISMID: 40 Years of Science, Innovation and Infrastructure Assessment for Resilient Cities

Damage to Tall Office Buildings in the Next Nankai-Trough Earthquake and the Mitigation Technologies

Takuya Nagae, Nagoya University

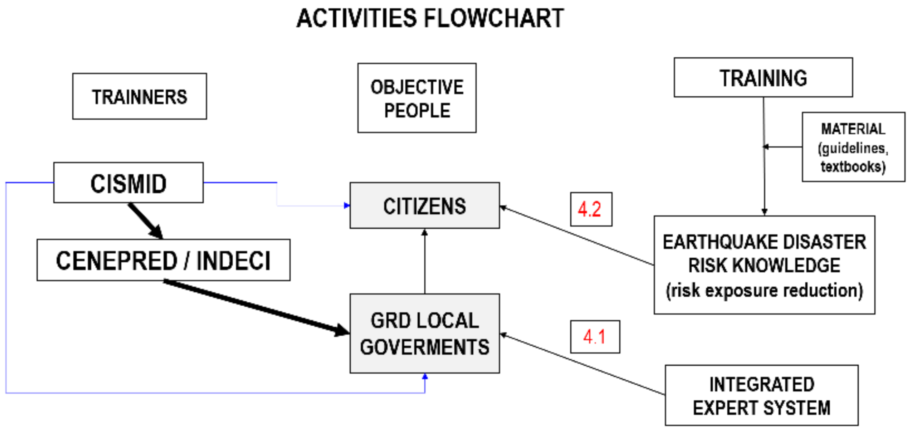


NAGAE Lab
長江　拓也　准教授
減災連携研究センター
現行基準
大振幅室内
基礎滑り構法
既存超高層骨組/耐震改修
崩壊限界
国立研究開発法人 防災科学技術研究所 (2006-2014)
NIED
技術開発／カーテンウォール内ジャイロ
カーテンウォール内のセンサで計測
地震発生
角速度計
傾斜計
層間変形角の算出
床加速度の算出
等価一自由度縮約
構造躯体の損傷評価
二次部材の損傷評価
設備機器の損傷評価
カーテンウォール機能で発光表示
関係者への情報伝達
設備損傷
Original model（Before repair)
Repaired model
Angle + Column thickness
Plate + Column thickness
Divide the column geometry
構造/非構造
デジタルツイン
センシング+レジリエンス評価システム 産官学協同
破断後補修
載荷点a
ボルト荷重
塑性エレメント
ピン
Experiment
Simulation
(カリフォルニア大学)
台湾國立成功大学 設計学院
（環境学研究科 協定）
鉄骨造レジリエンス
SSB
振子型滑り免震支承
設備機器類
台湾國家地震工程研究中心
（減災連携研究センター 協定）
次世代型免震構造
NAGOYA UNIVERSITY
Hazard analysis
Structural analysis
Damage analysis
Loss/downtime analysis
Coll./casualty analysis
facility definition D
(スイス工科大学)
確率論
$\lambda(DV)=\iiint G\langle DV|DM\rangle dG\langle DM|EDP\rangle dG\langle EDP|IM\rangle d\lambda(IM)$
評価体系 Performance Based Earthquake Engineering
15m
Top beam
Fixed boundary
Core wall
X-direction actuator
Foundation beam
Y-direction actuator
Loading platform
Holding actuator
6 DOF control
超高層モデル震動実験
天津大学 建築工程学院
（環境学研究科 協定）
コア壁耐震実験
清華大学
柱梁接合部メカニズム
RC超高層設計の高度化 国際連携
免震
地盤上
上部終局評価
基礎・地盤相互作用
wallstat
高耐震木造住宅 首都圏レジリエンスPJ

SATREPS G4

Propósitos del proyecto

1. Desarrollo de recursos humanos para utilizar eficazmente SEIDAS.
2. Capacitar a funcionarios y tomadores de decisiones que trabajan en la gestión del riesgo de desastres (GRD) en el uso de esta herramienta, a fin de elaborar recomendaciones de respuesta rápida y oportuna ante emergencias, basadas en los daños y pérdidas calculados y referenciados en un sistema de información geográfica.



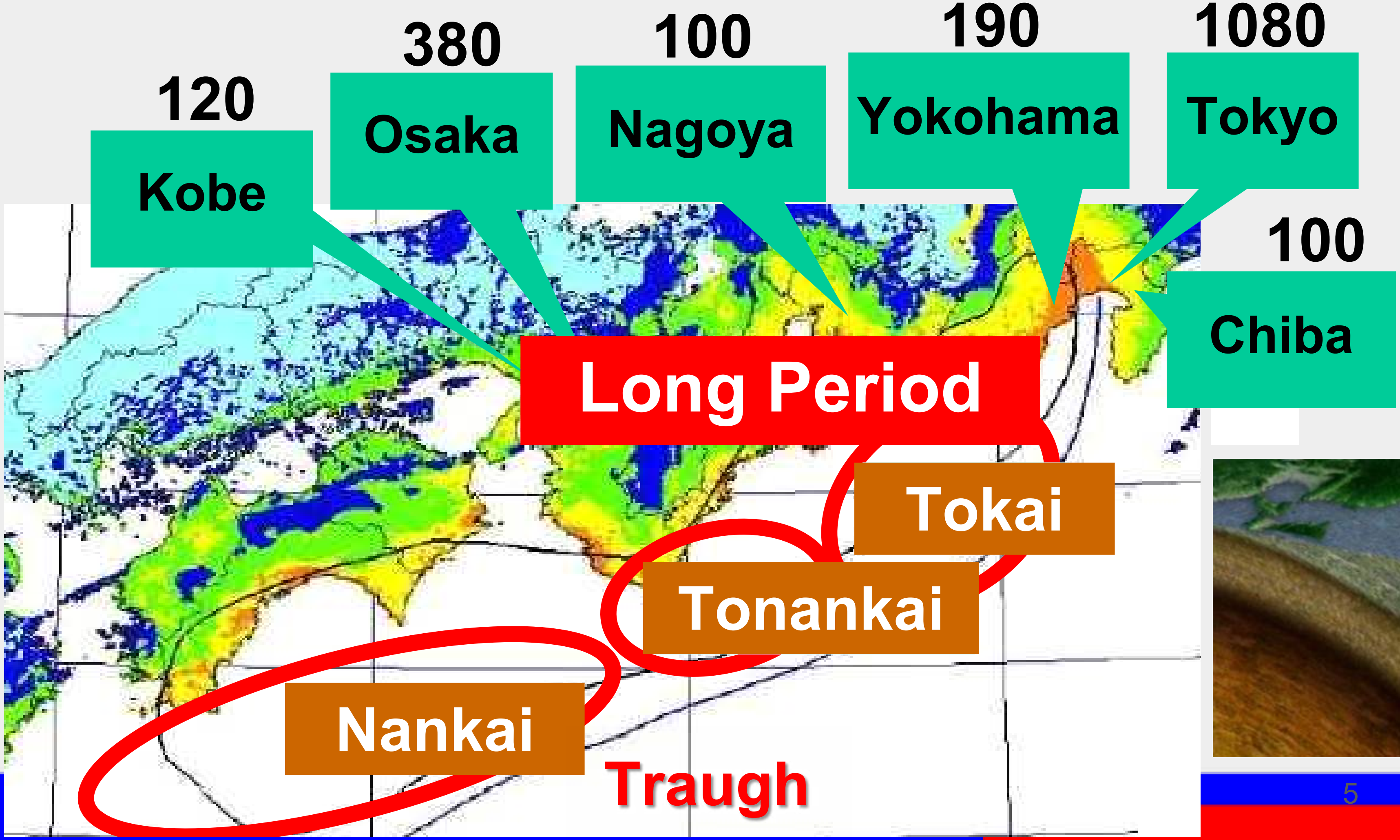
Protocolos de investigación

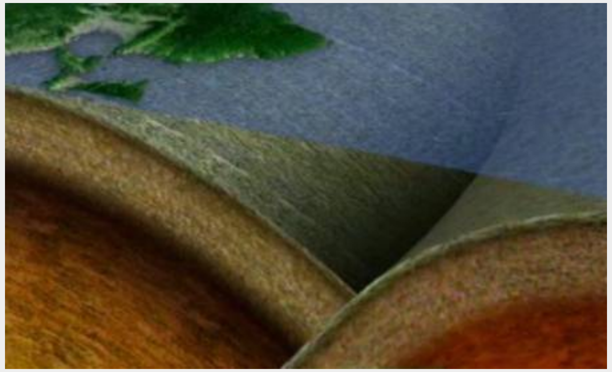
1. Talleres de promoción sobre el Proyecto PJ
2. Programas de capacitación en SEIDAS
3. Herramientas educativas sobre daños sísmicos
4. Manuales sobre las herramientas pertinentes




High-Rise Building Situations

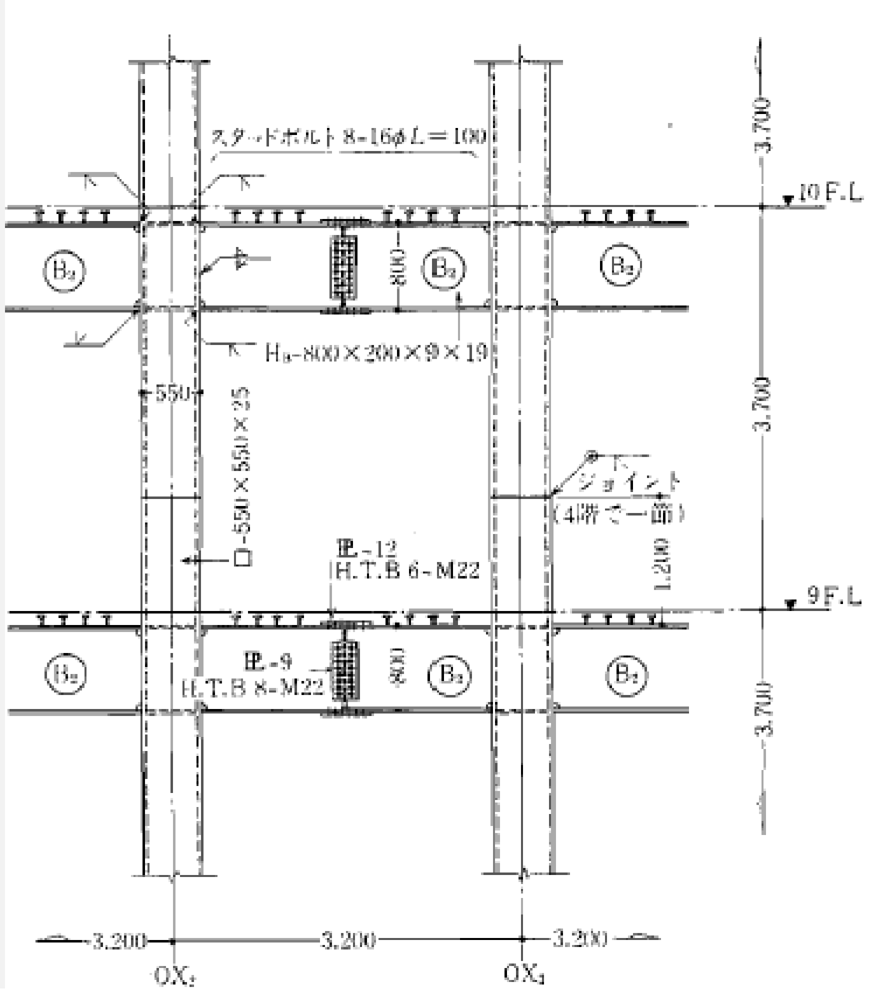
Symbolic new structures will be subjected to the next Nankai Trough EQ for the first time.

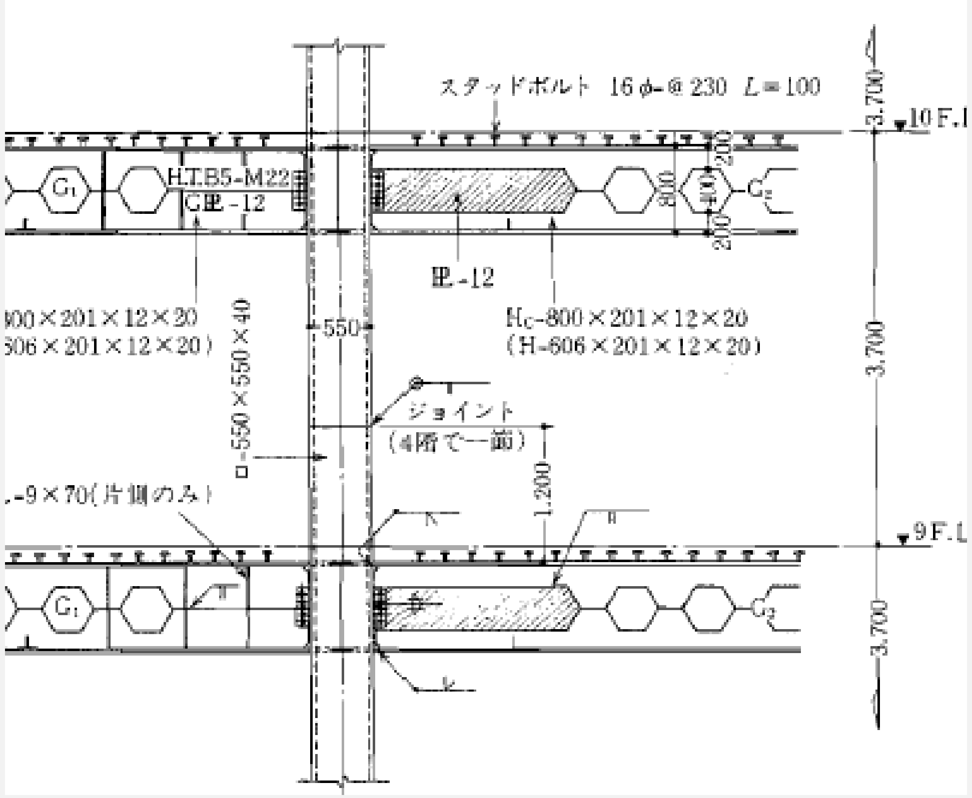




1960's
Kasumigaseki Building

Old type design, poor connection details

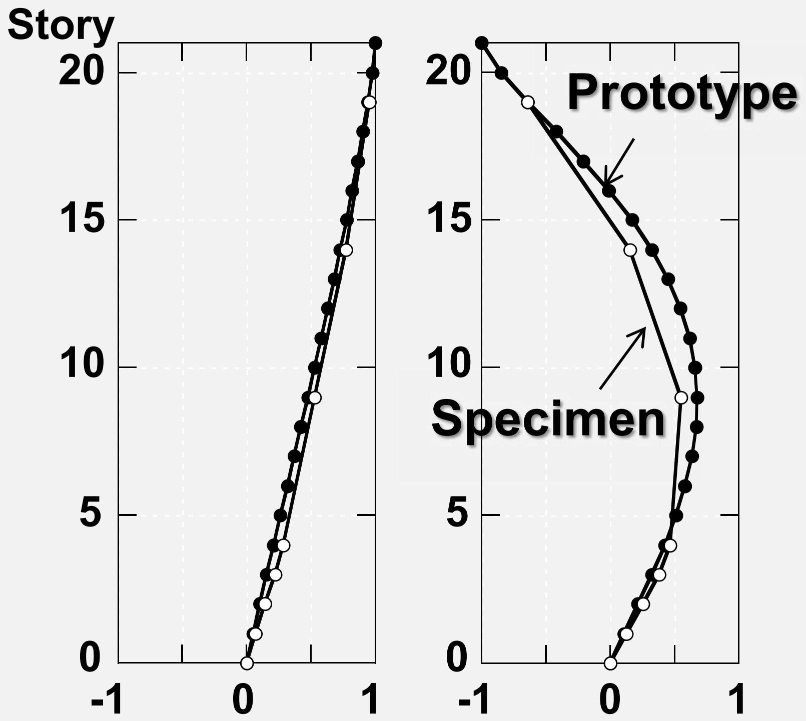


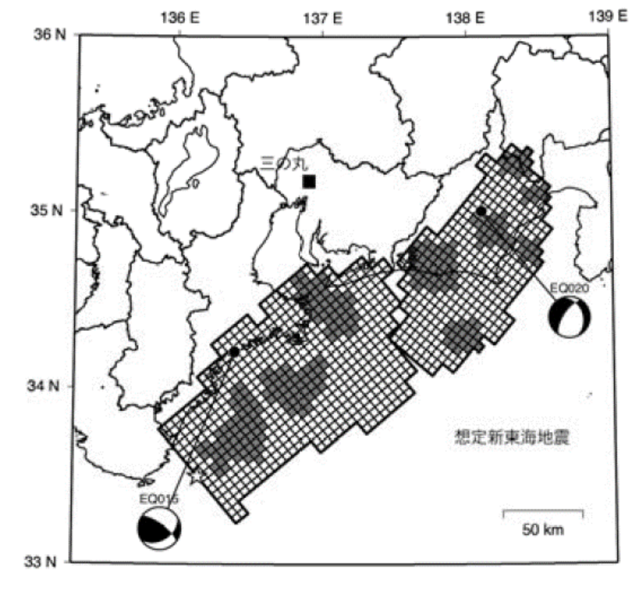


1970年代の設計資料

Capacity to the connection fracture
→ Relatively low

2007 Substitute Structure Test

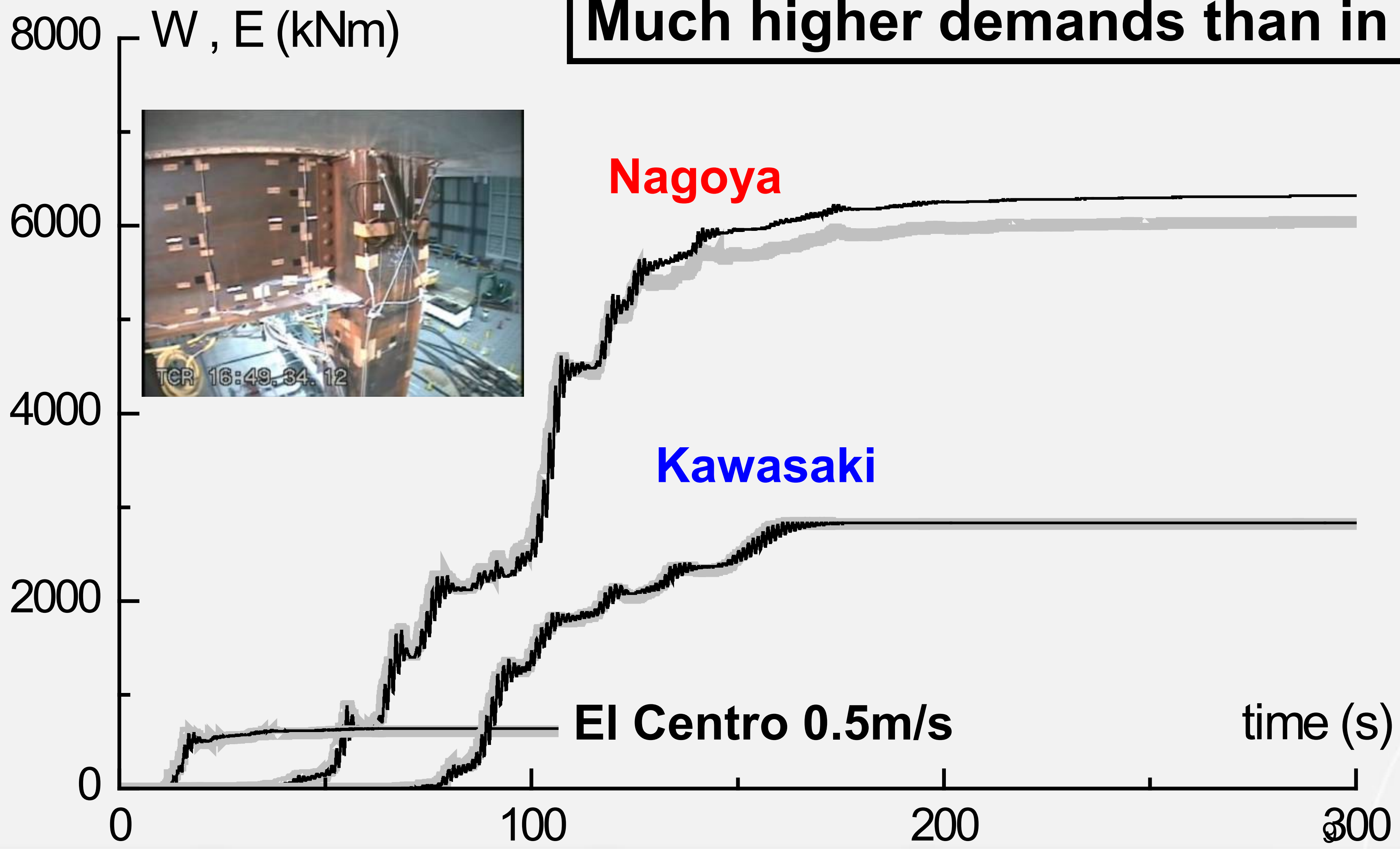




Seismic Resistance Capacity of High-Rise Buildings subjected to Long-Period Ground Motions : E-Defense Shaking Table Test,
Yulin Chung, Takuya Nagae, Toko Hitaka, Masayoshi Nakashima, Journal of Structural Engineering, ASCE , 136 (6), pp 637-644, 2010

Total input energy

Much higher demands than in DBE



Seismic Resistance Capacity of High-Rise Buildings subjected to Long-Period Ground Motions : E-Defense Shaking Table Test,
Yulin Chung, Takuya Nagae, Toko Hitaka, Masayoshi Nakashima, Journal of Structural Engineering, ASCE , 136 (6), pp 637-644, 2010

Social reactions

2009. 1 Mainichi

毎日新聞

科学

高いビルほど「ゆらーり」に弱い

長周期地震動実験が示す深刻な被害

東海地震や東南海地震など規模の大きな地震では、「長周期地震動」というゆっくりした揺れが生じる。超高層ビルに被害を与えやすいとされるため、実験用に建てたビルを実際に揺らす大規模実験が3月、初めて行われた。重大な損傷を受けることがわかり、専門家は耐震補強が必要だと指摘している。【野田武、写真も】

超高層ビルを模して実物大規模で揺らされた実験用ビル＝兵庫県三木市の防災科学技術研究所で

◆21階建てを想定

◆設計に考慮されず

2秒以上かけ1往復の揺れ

2009. 1 Asahi

朝日新聞

どうする長周期地震動

超高層ビル 補強へ動き

実験、「切れぬはず」が切れた

「最大振幅4メートル、6分」分析も

東京・大阪で調査・工事続々

超高層ビルのモデルを長周期地震動で揺らすと、柱の接合部がちぎれた＝08年3月、兵庫県三木市のEディフェンス、西畑志朗撮影

新宿センタービルで進んでいる工事

設置する制震装置(●) 24の各フロアに12台、計288台取り付ける

Macro model representing entire structure to evaluate dynamic response demands

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

journal homepage: www.elsevier.com/locate/jcsr

ELSEVIER

Seismic and collapse behavior of existing high-rise steel buildings under long-period earthquakes

Jialiang Jin [a,*], Takuya Nagae [b,*], Yu-Lin Chung [c]

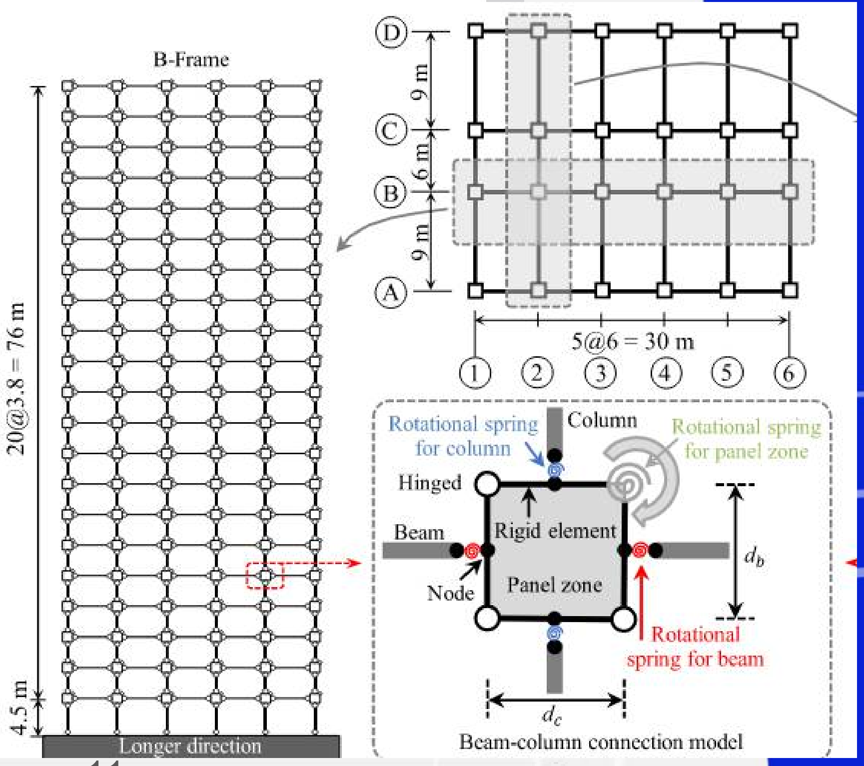
[a] *Graduate School of Environmental Studies, Nagoya University, 4648601, Aichi, Nagoya, Japan*
[b] *Disaster Mitigation Research Center, Nagoya University, 4648601, Aichi, Nagoya, Japan*
[c] *Department of Architecture, National Cheng Kung University, 70101 Tainan, Taiwan*

A R T I C L E I N F O

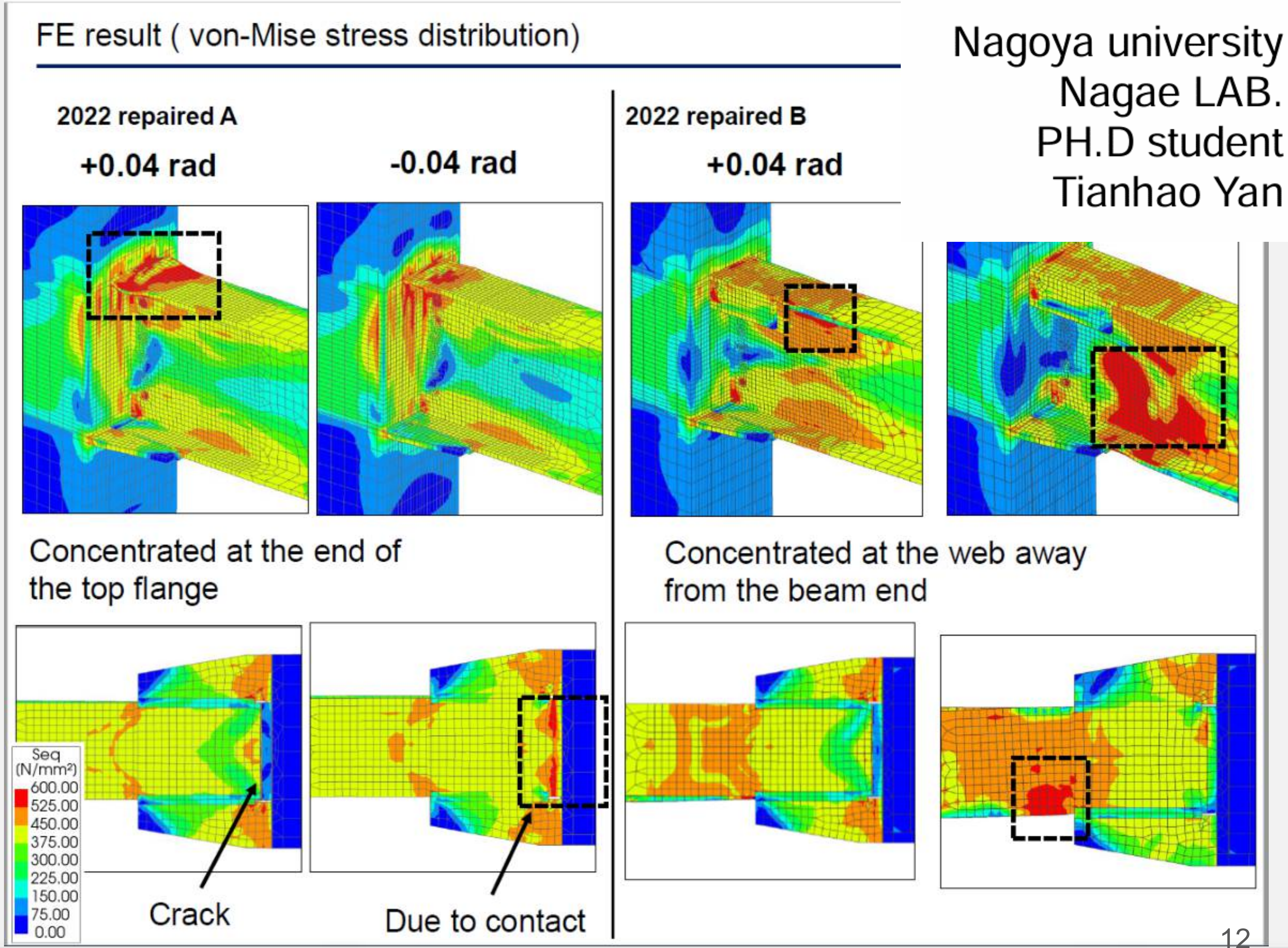
Keywords:
High-rise steel building
E-Defense shaking table test
Cyclic pushover analysis
Long-period ground motion
Beam-column connection
Fatigue fracture

A B S T R A C T

This work presented the experimental and numerical evaluation of th
existing high-rise steel buildings subjected to long-period ground m
Defense, 2008) was performed by the full-scale shaking table tests o
Accordingly, a nonlinear rotational spring model was used in the r
stiffness/strength deterioration and fatigue fracture of beam-colum
was utilized to account for such effect using seismic response data f
numerical model parameters were derived and validated with the in
substructure. Herein, a well agreement on the seismic failure behav
found in this situation. Furthermore, both field-welded and shop-wel
were included for comparison. For the 21-story prototype steel bu
merical collapse analyses were performed. The above revised model
time history analysis were conducted to simulate and compare the
slabs on the 21-story prototype building. Finally, a cyclic loading p
and the related ultimate failure behavior of the high-rise building wa



Simulation for repaired connections

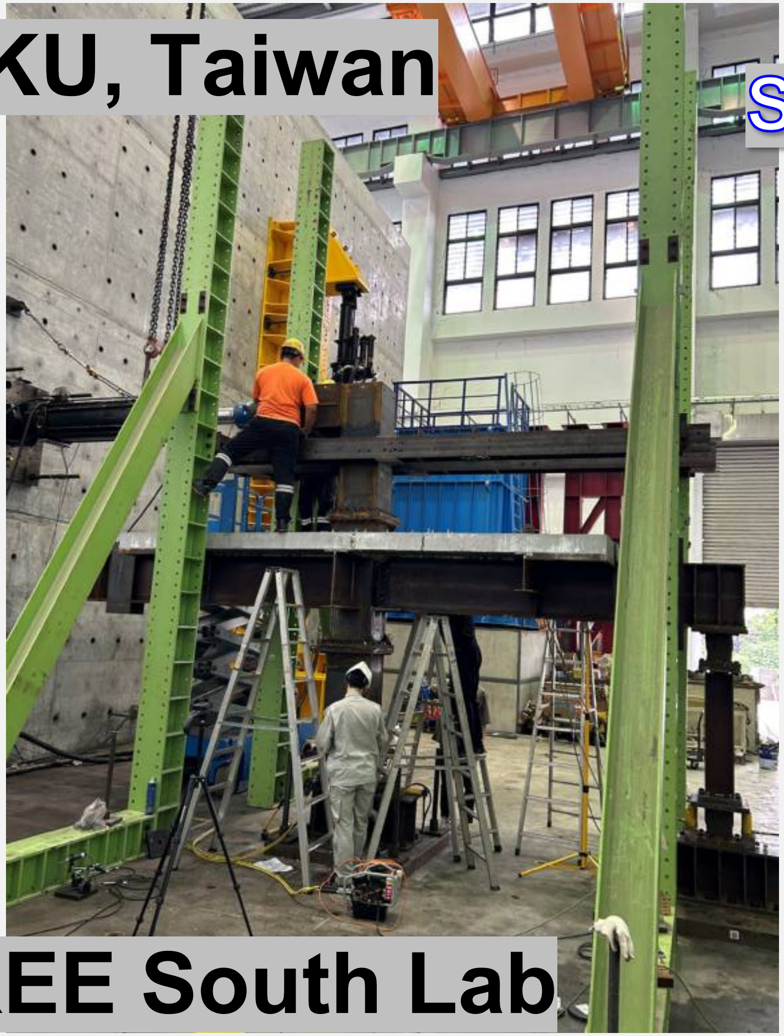


Nagoya university
Nagae LAB.
PH.D student
Tianhao Yan

Post-earthquake repair of welded unreinforced flange-bolted web connections considering composite slab effects, Jin JL, Chung YL, Nagae T, Yan TH, Shigeta E, Lin KC, JOURNAL OF CONSTRUCTIONAL STEEL RESEARCH, Volume 221, 2024.10.

Not just repaired but also enhanced connections

NCKU, Taiwan



NCREE South Lab

August, 2023

Shigeta from Nagoya University

April-September, 2024

Students of Nagoya University

Post-earthquake repair of welded unreinforced flange-bolted web connections considering composite slab effects, Jin JL, Chung YL, Nagae T, Yan TH, Shigeta E, Lin KC, JOURNAL OF CONSTRUCTIONAL STEEL RESEARCH, Volume 221, 2024.10.

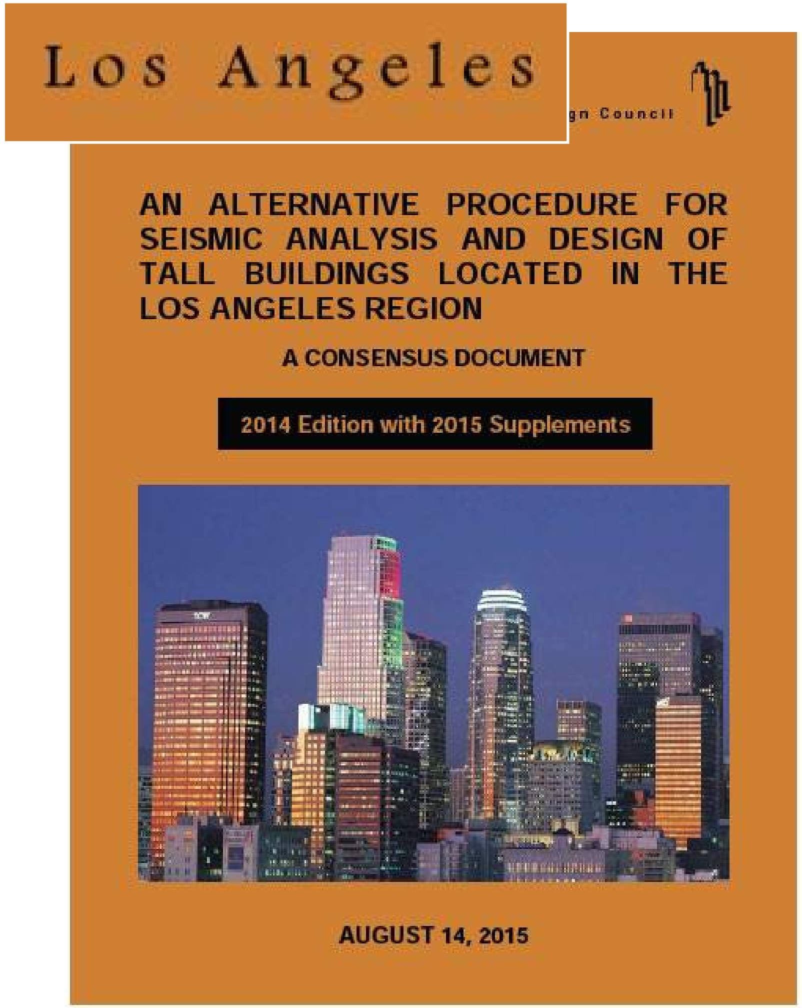
Old high-rise issue similarly pointed out in SF and LA

SF 2017

LA 2017

Fifth floor Conference Facilities Federal Reserve Bank of Los Angeles
950 South Grand Avenue at Olympic Boulevard Los Angeles , California

An example of international situations


Los Angeles
...gn Council

AN ALTERNATIVE PROCEDURE FOR SEISMIC ANALYSIS AND DESIGN OF TALL BUILDINGS LOCATED IN THE LOS ANGELES REGION

A CONSENSUS DOCUMENT

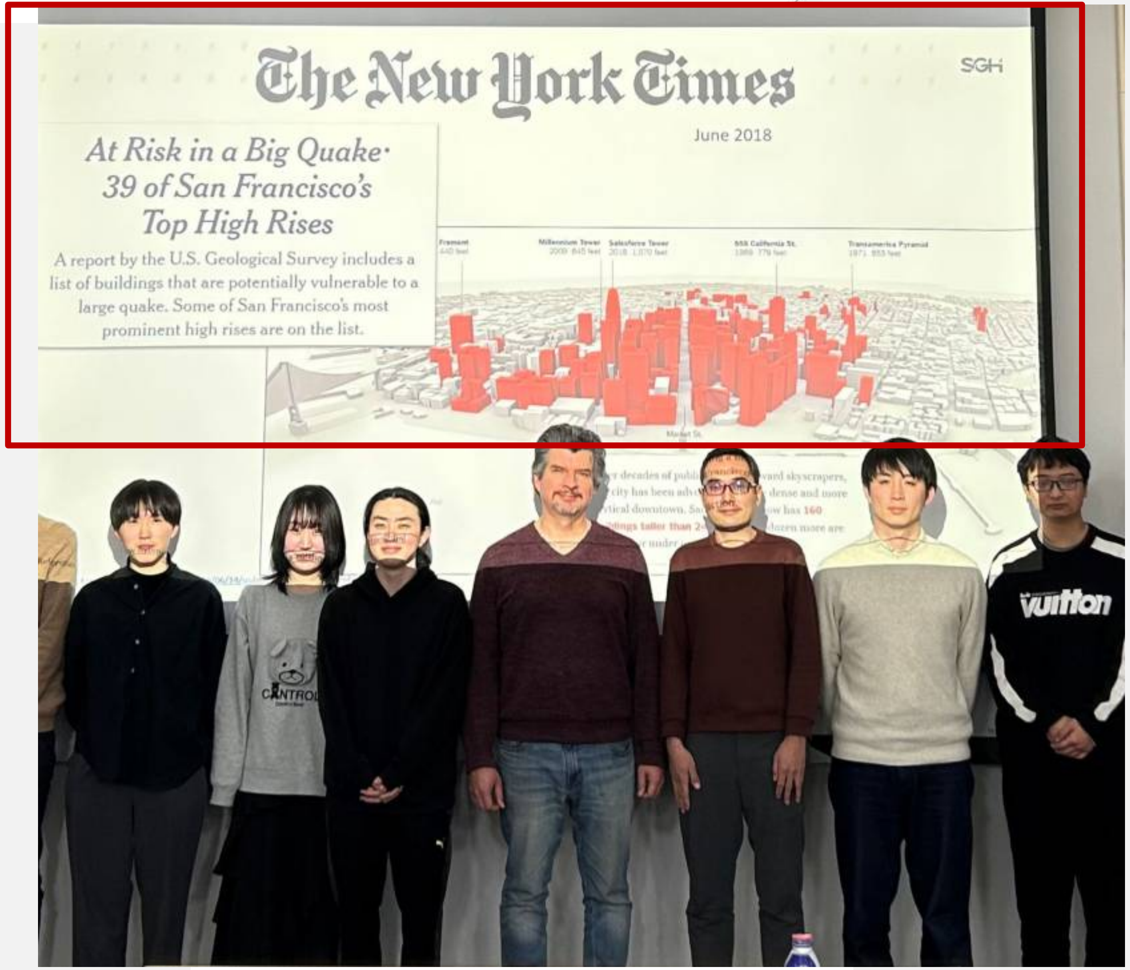
2014 Edition with 2015 Supplements

AUGUST 14, 2015

LATBSDC Guideline Updates

Leading Performance Based Design for high-rises in U.S.

Los Angeles Tall Buildings Structural Design Council



US design firm SGH

At Risk in a Big Quake 39 of San Francisco's Top High Rises

Dr. Paul Cordova

2025.2

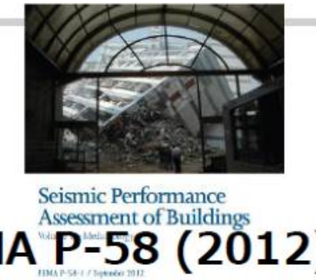
PEER assessment methodologies

2002-2004

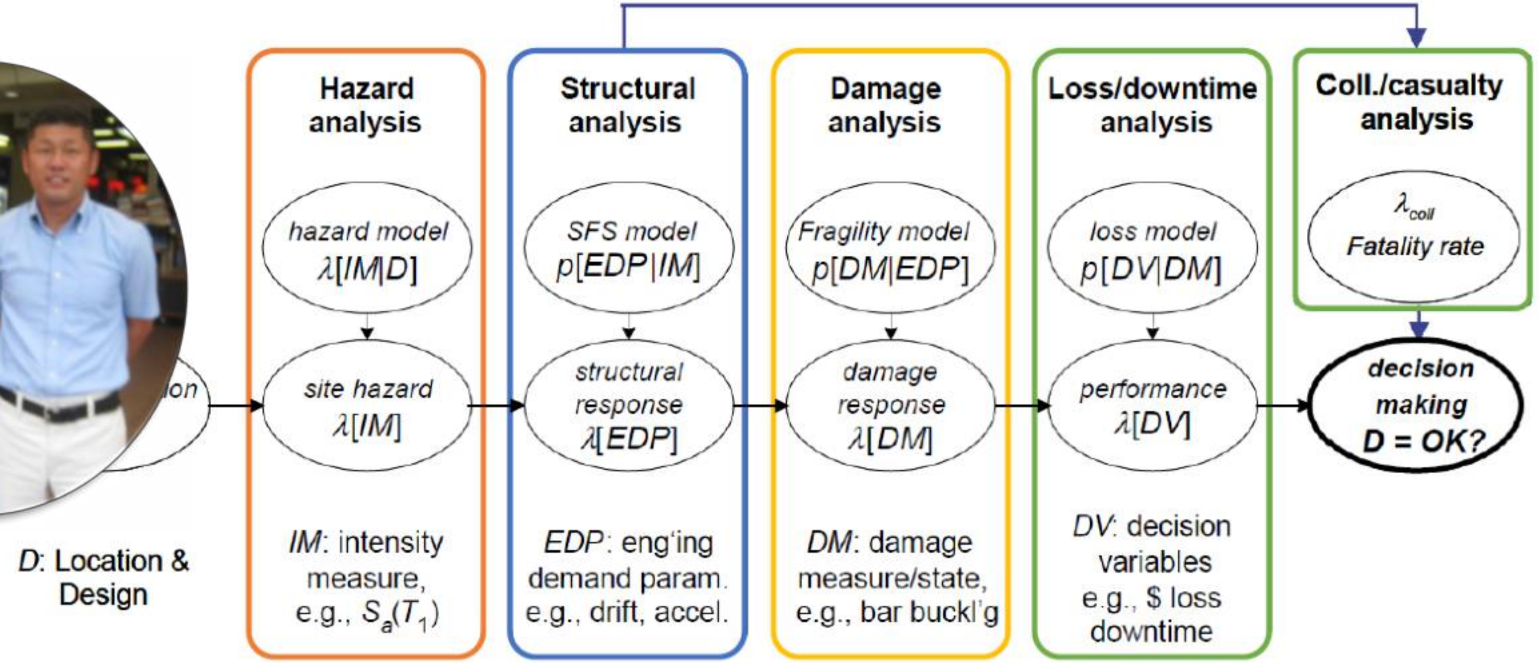
Probabilistic Seismic Performance Evaluation based on PBEE

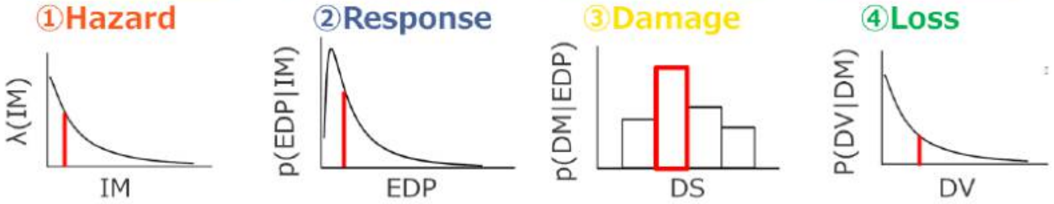
Valuation equation

$$\lambda(DV) = \iiint G\langle DV|DM\rangle dG\langle DM|EDP\rangle dG\langle EDP|IM\rangle d\lambda(IM)$$



FEMA P-58 (2012)





Takaya & Jin

excluded from the integral on the right side of the equation. As a result, Equation (1) in FEMA P-58 is converted to Equation (2) for loss evaluation in this study.

$$\lambda(DV) = \iiint G(DV|DS)\,dG(DS|EDP)dG(EDP|IM)d\lambda(IM) \tag{1}$$

$$\lambda(DV|IM) = \int G(DV|EDP)dG(EDP|IM) \tag{2}$$

Here, $G(X \mid Y)$ represents the probability of outcome X given the condition Y holds, and $\lambda(X)$ denotes the annual exceedance frequency of X.

PBEE Approach (2024)

buildings

Article

Practical Repair Cost Assessment of Steel Office Buildings with Diverse Beam-to-Column Connection Types in Japan

Kazuki Takaya [1], Jialiang Jin [1] and Takuya Nagae [2,*]

A two-dimensional frame model, interconnected by horizontal rigid links, was developed in the OpenSees platform [33] to represent the longitudinal frames of the prototype, as shown in Figure 2a. As shown in Figure 2b, beams and columns were modeled using elastic beam-column elements with nonlinear rotational springs at each end, following a concentrated plasticity approach. Panel zones were represented by pin-connected rigid elements arranged in a quadrilateral configuration, with a rotational spring modeled as a zero-length element at one of the corner joints. BRBs were modeled as individual truss elements with equivalent stiffness connecting two work-point nodes [34,35].

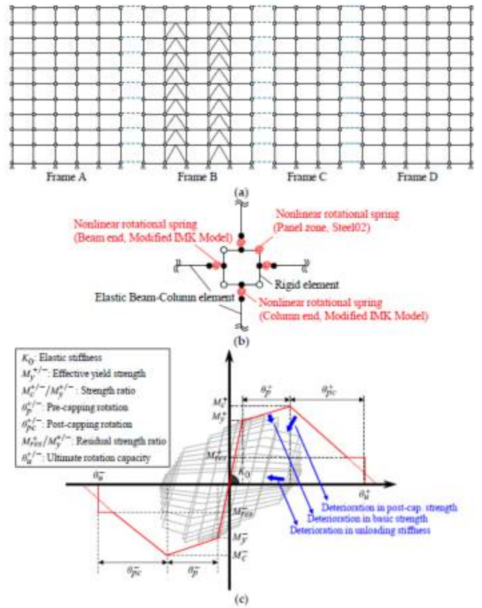


Figure 2. (a) Analytical model of the prototype; (b) beam-to-column connection model; (c) modified IMK model [15,36].

are continuously improving. However, loss functions developed to provide a more practical evaluation of repair costs compared to existing methods fail to replicate changes in deformation mechanisms caused by the performance of individual components. This highlights a knowledge gap regarding the gap between actual performance and the performance that can be represented in story loss functions. This study aims to quantitatively assess the impact of beam-to-column connection types and their deformation mechanisms on loss functions in Japanese steel buildings. By clarifying the impact of beam-to-column connection performance on story loss functions, the applicability of the story loss functions to different deformation mechanisms is expanded. Loss functions appropriately evaluate losses without clearly identifying the types, quantities, or damage mechanisms of individual components. Therefore, it enables the improvement of balanced seismic resilience, considering both structural and non-structural components from a macro perspective that includes the entire building.

First, a numerical analysis model of a steel frame is created based on experimental data of beam-to-column connections used in Japan. Then, based on the member deformation corresponding to the member model and the relationship between member deformation and IDR from numerical analysis, the beam fragility representing each story is created, and trends for each model and story will be analyzed. Subsequently, story loss functions for the structure are created from the beam fragilities and other structural component fragilities, and the impact of deformation mechanisms is quantitatively assessed. Finally, by calculating the building response using the Incremental Capacity Spectrum Method (CSM) [26] and evaluating the building repair costs with the loss functions, the effectiveness of the loss functions in practical procedures can be confirmed.

2. Repair Cost Assessment Procedure

2.1. Comprehensive Seismic Loss Assessment Using a Probabilistic Approach

The probabilistic seismic performance assessment framework outlined in FEMA P-58 was developed at PEER in the early 2000s [27]. This PEER procedure segments the process from earthquake occurrence to damage initiation into four stages and evaluates the annual exceedance frequency of loss by integrating the conditional occurrence probabilities for each step sequentially: Intensity Measure (*IM*), Engineering Demand Parameter (*EDP*), Damage State (*DS*), and Decision Variables (*DV*), as described in Equation (1). In FEMA P-58, Equation (1) is statistically derived using Monte Carlo Simulation (MCS). This study follows FEMA P-58 procedures to conduct loss evaluation using MCS.

For repair cost assessment, the story loss function defined in Section 2.3 (Ref. [8]) is employed, enabling direct evaluation of repair costs based on the EDP through a function that substitutes fragility relationships for DS and DV. Additionally, to further assess repair costs for each earthquake intensity level, the probability function of earthquake intensity is
excluded from the integral on the right side of the equation. As a result, Equation (1) in FEMA P-58 is converted to Equation (2) for loss evaluation in this study.

$$\lambda(DV) = \iiint G(DV|DS)\,dG(DS|EDP)dG(EDP|IM)d\lambda(IM) \tag{1}$$

$$\lambda(DV|IM) = \int G(DV|EDP)dG(EDP|IM) \tag{2}$$

Here, $G(X \mid Y)$ represents the probability of outcome X given the condition Y holds, and $\lambda(X)$ denotes the annual exceedance frequency of X.

2.2. Capacity Spectrum Method

In this study, the Capacity Spectrum Method (CSM) is used to determine the building responses. The CSM calculates the maximum seismic response of an equivalent single-degree-of-freedom (SDOF) system without the need for nonlinear time history analysis

related to seismic motion characteristics.

The performance curve for the equivalent SDOF system is derived from the results of static pushover analysis, as calculated using Equations (3) and (4):

$$S_a = \frac{\sum_{i=1}^{N} P_i\delta_i}{\sum_{i=1}^{N} m_i\delta_i} \tag{3}$$

$$S_d = \frac{\sum_{i=1}^{N} m_i\delta_i^2}{\sum_{i=1}^{N} m_i\delta_i} \tag{4}$$

where S_a and S_d represent the lateral shear force and the lateral displacement of the equivalent SDOF system, P_i is the lateral force acting on the i-th story, δ_i is the lateral displacement of the i-th story, m_i is the mass of the i-th story, and N is the number of stories.

The damping factor h_{eq} is derived from an equation that evaluates the hysteretic damping constant of the entire frame, calculated based on the component accumulation method [26] using Equations (5) and (6). In Japanese design, a perfectly elastoplastic model based on a peak-oriented hysteresis rule is commonly used as the steady-state loop model to calculate the damping curve. However, for steel materials that experience an increase in strength after yielding and maintain stiffness even after unloading, the perfectly elastoplastic model may underestimate the damping. Therefore, in this study, a normal bilinear model with constant secondary stiffness after yielding is adopted for the steady-state loop model of each structural member (including beams, columns, panel zones, and BRBs) to provide a more accurate evaluation of the damping curve, as calculated by Equation (7).

$$h_{eq} = 0.8h_{eq}' + h_0 \tag{5}$$

$$h_{eq}' = \frac{1}{4\pi}\frac{\sum_{j=1}^{n_y} \Delta W_j}{\sum_{i=1}^{N} P_i\delta_i/2} = \frac{\sum_{j=1}^{n_y} h_{eqj} W_j}{\sum_{i=1}^{N} P_i\delta_i/2} \tag{6}$$

$$h_{eqj} = \frac{2}{\pi}\frac{(1-p)(\mu-1)}{\mu + p\mu(\mu-1)} \tag{7}$$

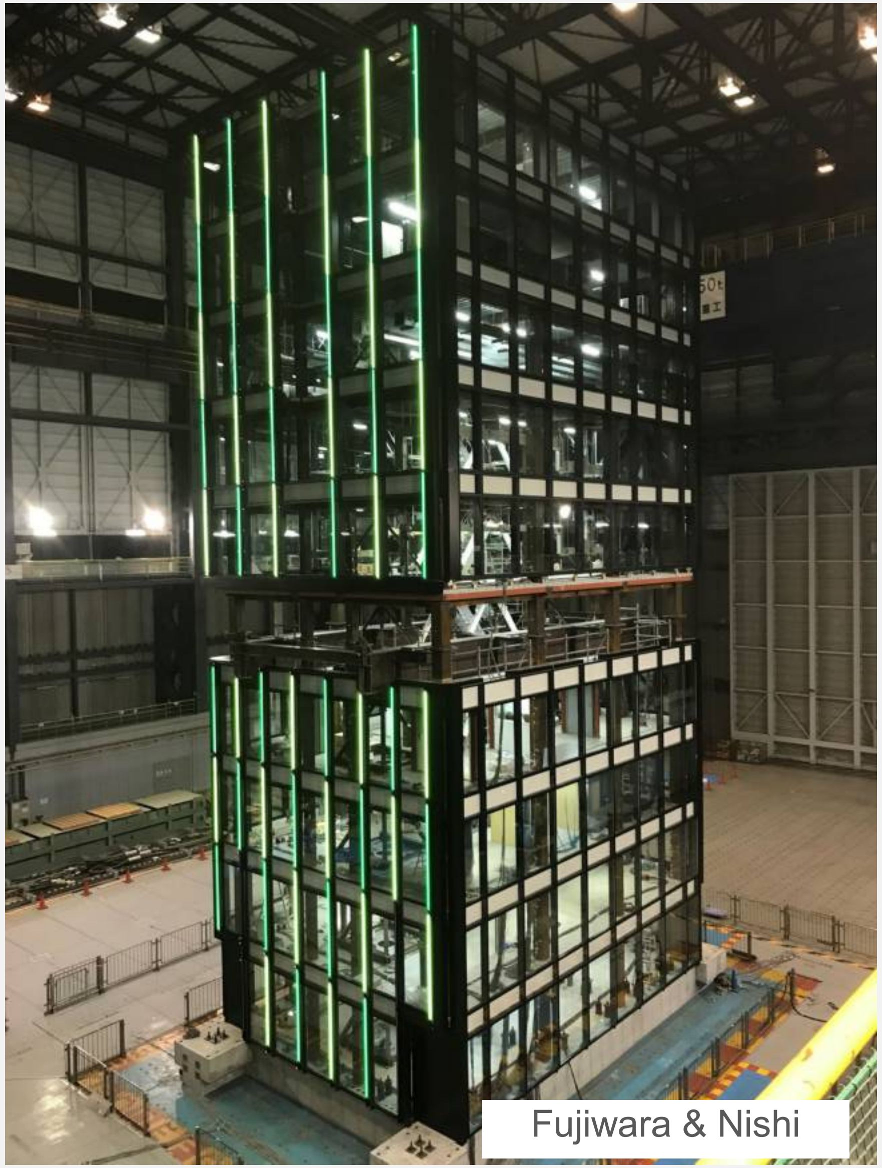
Here, h_{eq}' represent the equivalent viscous damping factor of the equivalent SDOF system for the entire structure, h_0 is the internal damping factor of the equivalent SDOF system, ΔW_j and W_j are the hysteretic energy absorption and potential energy at member j, respectively; h_{eqj} and μ_j are the hysteretic damping constant and ductility factor at member j; n_y denotes the number of member-end hinges formed at the given step.

Additionally, to calculate the response of each story from the maximum response of the equivalent SDOF system, the PFA response distribution $PFA(i)$ is determined based on the study by Ishihara et al. [28], and the maximum IDR distribution $IDR(i)$ is derived from Mori et al. [29], using Equations (8) and (9), respectively.

$$PFA(i) = \sqrt{\left(\beta_1 U_1 S_{a,1}^I\right)^2 + \sum_{k=2}^{3}\left(\beta_k U_k S_{a,k}^E\right)^2}, (\alpha_i > 0.4S_{a,1}^I) \tag{8}$$

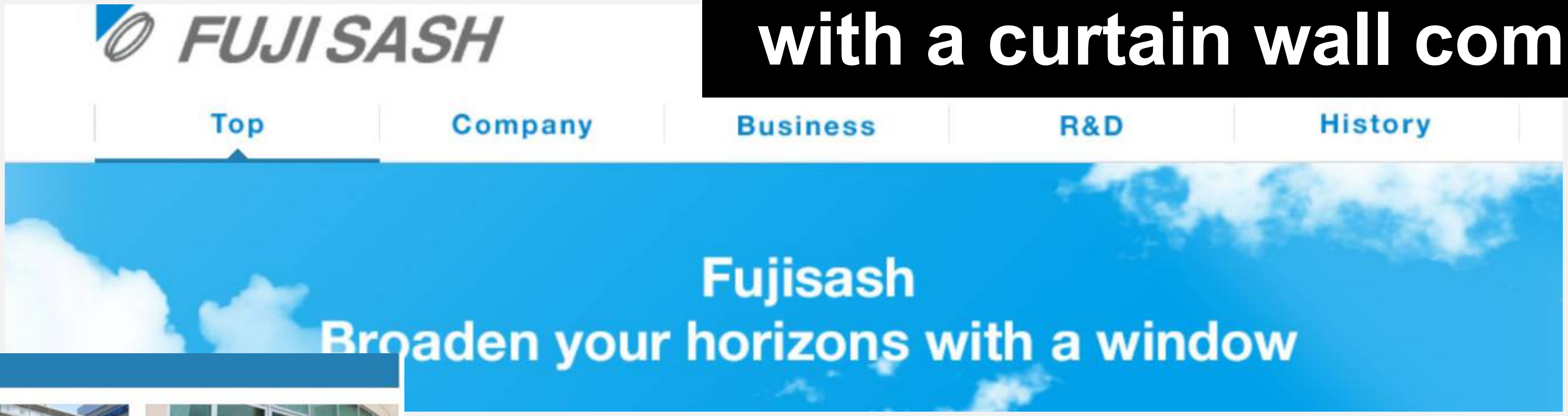
$$IDR(i) = \sqrt{\left(\beta_1 U_1{}' S_{d,1}^I\right)^2 + \sum_{k=2}^{3}\left(\beta_k U_k S_{d,k}^E\right)^2} \tag{9}$$

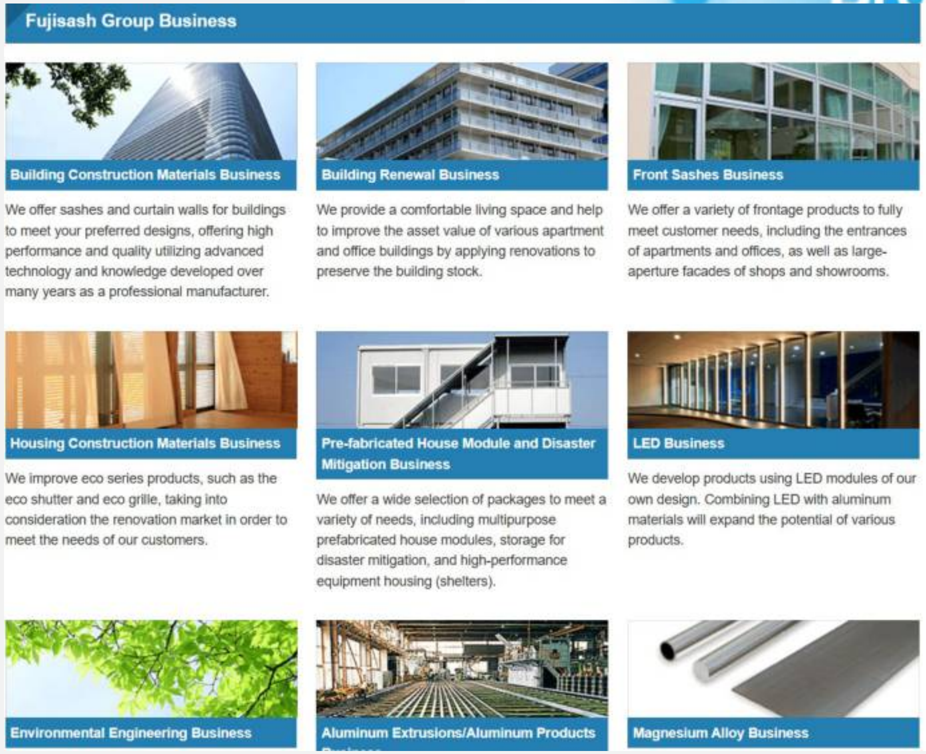
Sensing technologies in NIED 2023.2



Full-scale Shaking Table Tests on a 10-story Steel Moment-resisting Frame Building with Buckling-restrained Braces, J. Fujiwara, J. Jin, J. Li, T. Yan, R. Nishi, A. Kishida, K. Kajiwara, T. Nagae, T, Okazaki, T. Asai, EARTHQUAKE ENGINEERING & STRUCTURAL DYNAMICS, 2026.8

Business model based development with a curtain wall company





Fujisash Group Business

Building Construction Materials Business
We offer sashes and curtain walls for buildings to meet your preferred designs, offering high performance and quality utilizing advanced technology and knowledge developed over many years as a professional manufacturer.

Building Renewal Business
We provide a comfortable living space and help to improve the asset value of various apartment and office buildings by applying renovations to preserve the building stock.

Front Sashes Business
We offer a variety of frontage products to fully meet customer needs, including the entrances of apartments and offices, as well as large-aperture facades of shops and showrooms.

Housing Construction Materials Business
We improve eco series products, such as the eco shutter and eco grille, taking into consideration the renovation market in order to meet the needs of our customers.

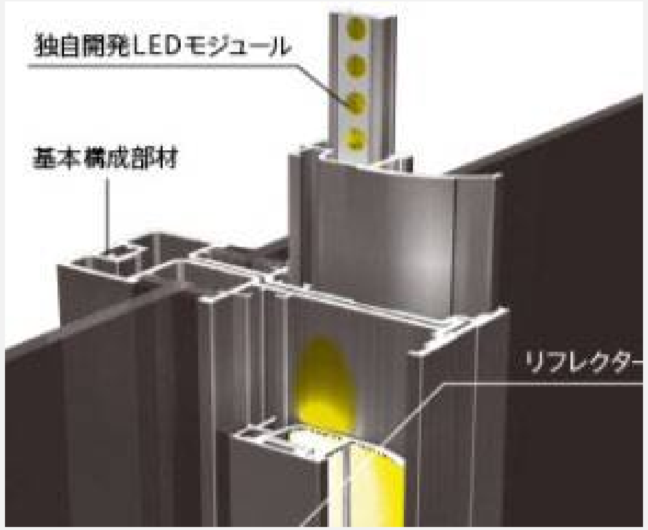
Pre-fabricated House Module and Disaster Mitigation Business
We offer a wide selection of packages to meet a variety of needs, including multipurpose prefabricated house modules, storage for disaster mitigation, and high-performance equipment housing (shelters).

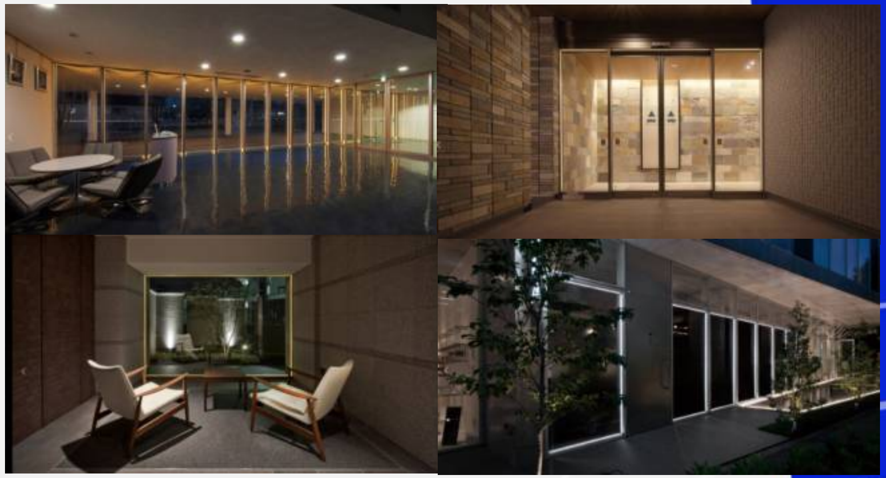
LED Business
We develop products using LED modules of our own design. Combining LED with aluminum materials will expand the potential of various products.

Environmental Engineering Business

Aluminum Extrusions/Aluminum Products

Magnesium Alloy Business



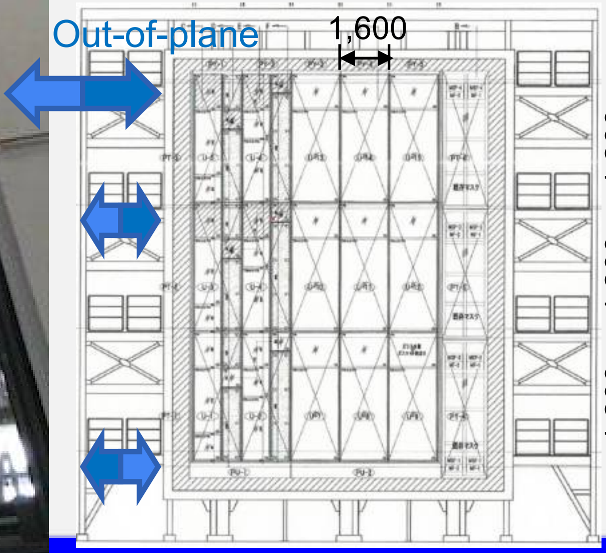


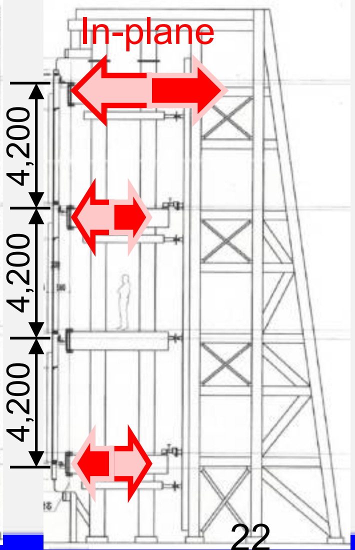
Assessment of a Curtain Wall System Used in High-Rise Buildings and Development of a Monitoring Method, S Toyao, T Nagae, J Chen, K Kajiwara, Y Kanzaki, YL Chung, International Conference in Commemoration of the 20th Anniversary of the 1999 Chi-Chi Earthquake, 2019.9

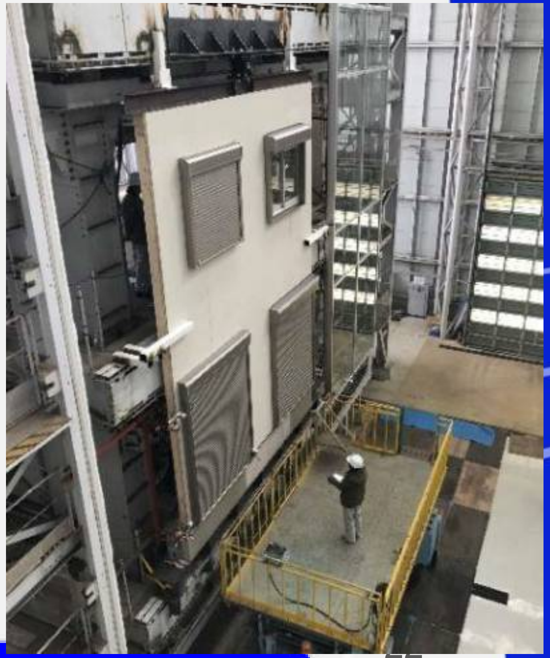
Distinguished smart curtain-wall system

Out-of-plane
IDR (1/100 rad)

In-plane
IDR (1/100 rad)







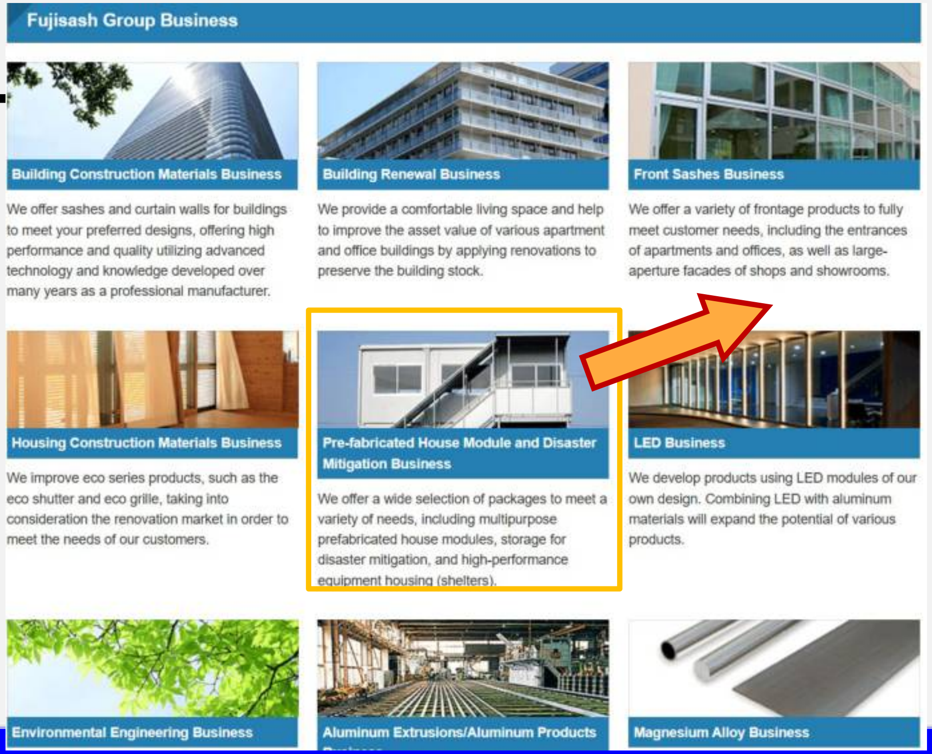
Inside device selection (gyro sensors)

科研費・挑戦的研究（開拓）

応急危険度判定の問題（特許2件）

Wood dwelling:
House building

L



2023.9.15 AIJ conference

包括的耐震性能評価実験
その21
カーテンウォール内蔵型センサ・アラートシステムにおけるジャイロセンサを用いた加速度評価

○鈴木里佳子　名古屋大学大学院環境学研究科 博士前期課程2年
髙谷和樹　名古屋大学大学院環境学研究科 博士後期課程・修士（工学）
浅井竜也　東京大学生産技術研究所 准教授・博士（工学）
長江拓也　名古屋大学減災連携研究センター 准教授・博士（工学）
神崎喜和　不二サッシ株式会社
日高和幸　文化シャッター株式会社
梶原浩一　防災科学技術研究所 博士（工学）
藤原　淳　防災科学技術研究所 博士（工学）
岸田明子　防災科学技術研究所 博士（工学）
荒井智治　不二サッシ株式会社
西　峻太　防災科学技術研究所 修士（工学）
齊藤直佳　不二サッシ株式会社
斉藤功男　不二サッシ株式会社

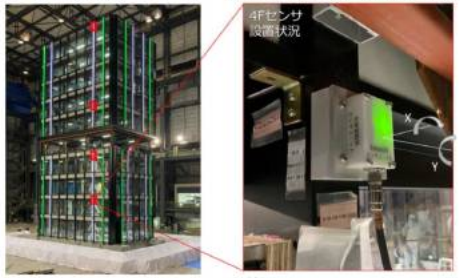
角速度→層間変形角　算出方法　13

層間変形角の算出

角速度 → 0.3Hz-30Hz バンドパスフィルタ → 積分 → 層間変形角

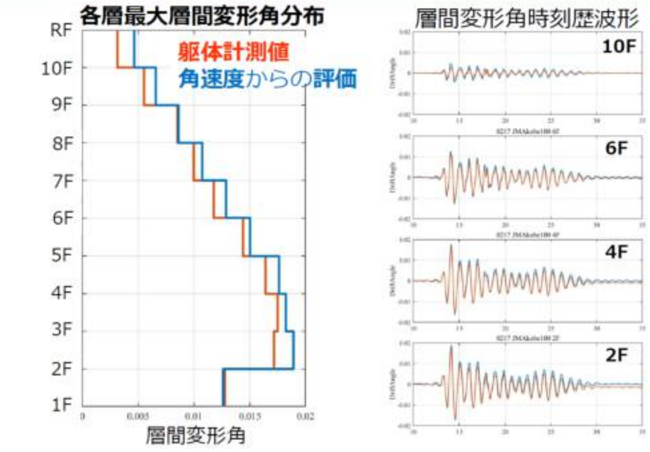
- 計測ノイズ除去
- 積分での発散を防ぐ

センサ設置のない層のデータ補完
・角速度計を設置している2・4・6・10階以外は、層間変形角を線形補完。



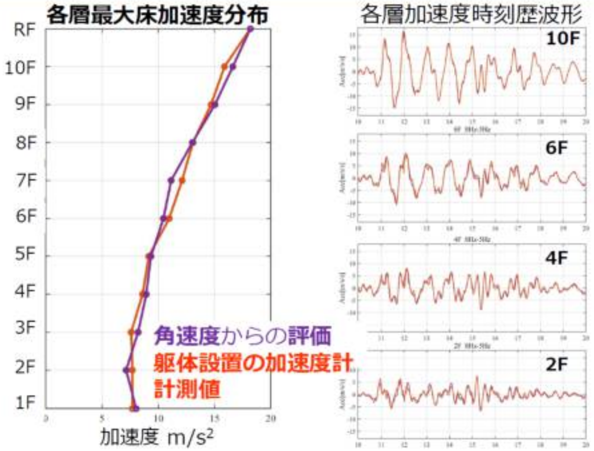
センサ設置状況

層間変形角算出結果　JMA神戸100%加振時　14



- **全体的に同様な精度で、おおむね適切に評価できる。**
- 積分で発散を防ぐために低周波数成分をカットしているため残留変形の評価ができない。

加速度算出結果　JMA神戸100%加振時　17



- **本手法で、おおむね適切に評価できている。**
- 相対加速度の足し合わせで算出するため、一つの層の誤差が全ての層に影響を及ぼすことに注意が必要。

④角速度を用いた建物等価一自由度縮約　18

目的：建物構造安全性評価

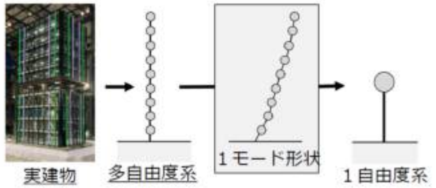
全体崩壊は、梁端の局所的破断の集積で決まる。

全体システムとしての力と変形の関係を評価し、強度低下の進行を判断する必要がある。

倒壊に向かうとき、骨組変形の進行は「1次モード」が支配的。

角速度評価の層間変位と床加速度を用いて建物を等価な一自由度系に縮約し、履歴形状を確認する。

E-defense18層鉄骨実験[6]

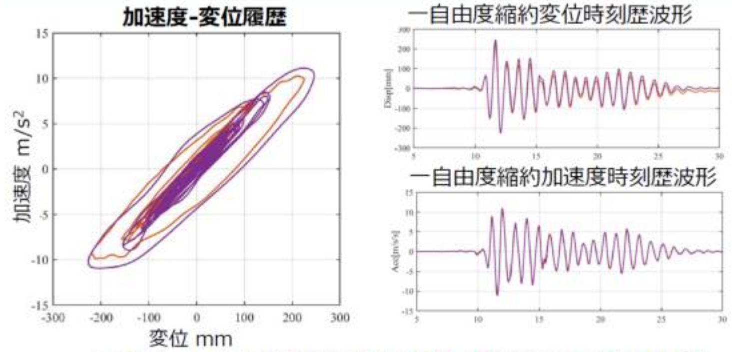


$$S_D(t) = \frac{\sum_{i=1}^{10} m_i \beta u_i \cdot \delta_i(t)}{\sum_{i=1}^{10} m_i \beta u_i}$$

$$S_A(t) = \frac{\sum_{i=1}^{10} P_i \cdot {}_1\delta_i(t)}{\sum_{i=1}^{10} m_i \cdot {}_1\delta_i(t)}$$

6)久保田淳, 髙橋元美, 鈴木芳隆, 澤本佳和, 田島祐治, 伊山 潤, 長江拓也, 鉄骨造18層骨組を対象とした振動台実験における長周期地震動による骨組崩壊挙動, 日本建築学会構造系論文集 | 746

一自由度縮約結果　JMA神戸100%加振時　19



角速度から評価　躯体設置加速度計・躯体設置レーザー変位計

- **1つの加速度計と、4つの角速度計で10層建物の力-変位関係を適切に評価できる。**
- 変位・加速度ともに1.1~1.3倍程度大きく評価される。

A NEW SENSING-ALERT CURTAIN WALL SYSTEM VERIFIED IN THE SEISMIC RESPONSES OF A 10-STORY BUILDING, K. Takaya, R. Suzuki, T. Nagae, T. Asai, J. Fujiwara, A. Kishida, R. Nishi, K. Kajiwara, Y. Kanzaki, 18th WCEE, 2024, Italy, Milan

A reproducing process in simulations

Cyclic pushover analysis for seismic response evaluation of a full-scale 10-story steel building tested on the E-Defense shake-table

Jialiang Jin[a], Takuya Nagae[a,*], Tatsuya Asai[b], Taichiro Okazaki[c], Jionghui Li[c], Dimitrios G. Lignos[d], Yu-Lin Chung[e], Jun Fujiwara[f], Akiko Kishida[f], Koichi Kajiwara[f]

[a] Nagoya University, 4648601, Nagoya, Japan
[b] The University of Tokyo, 1138654, Tokyo, Japan
[c] Hokkaido University, 0608628, Sapporo, Japan
[d] École Polytechnique Fédérale de Lausanne (EPFL), 1015, Lausanne, Switzerland
[e] National Cheng Kung University, 70101, Tainan, Taiwan
[f] National Research Institute for Earth Science and Disaster Resilience, 3050006, Hyogo, Japan

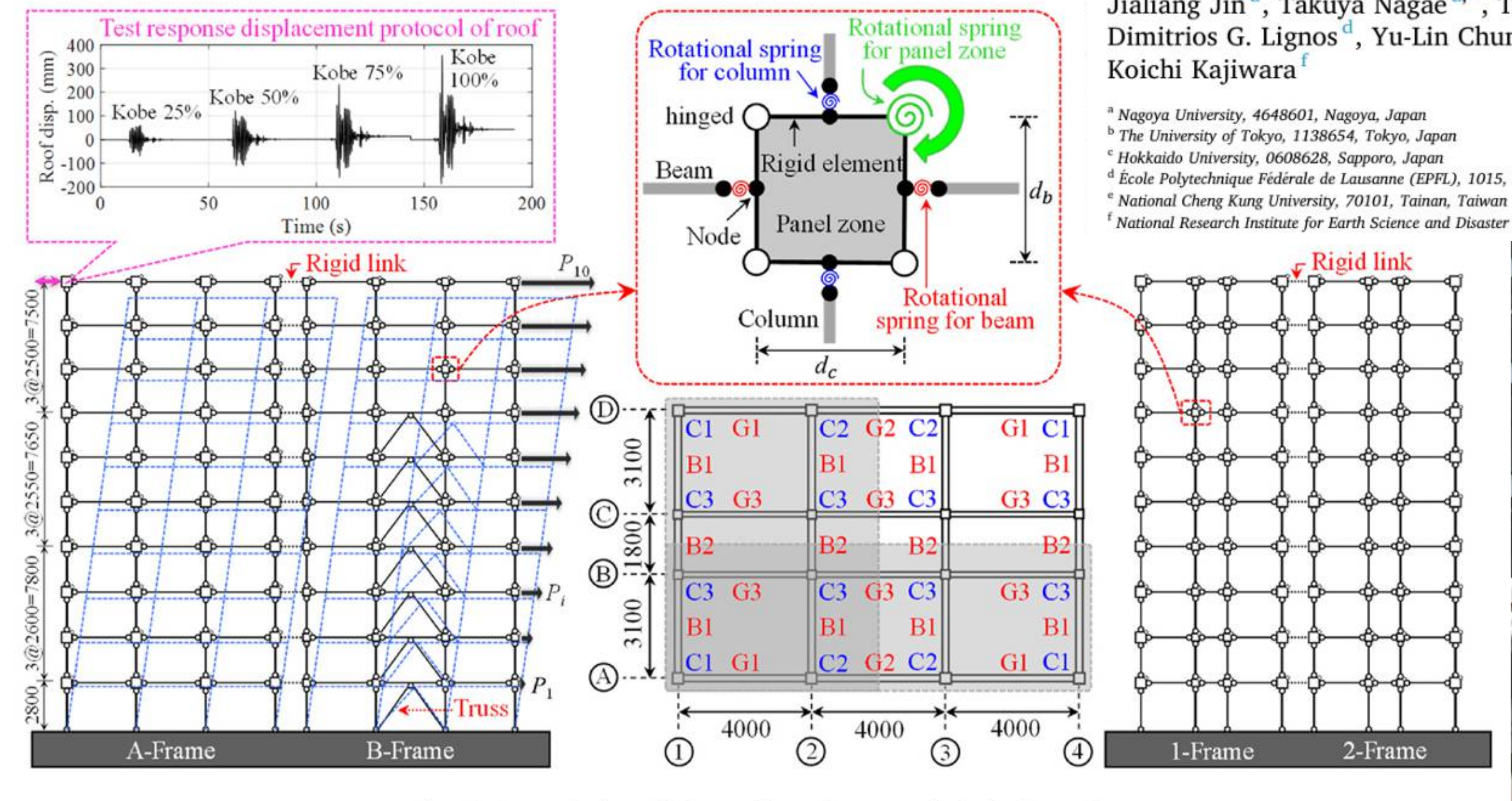


Fig. 4. Numerical model for cyclic pushover analysis (unit: mm).

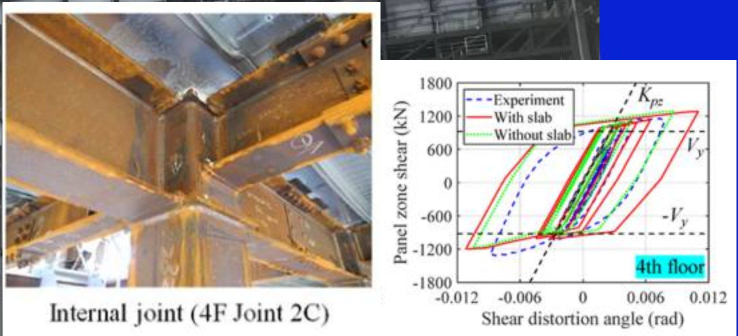


Fig. 17. Comparison of panel zone responses in internal frame (2-Frame).

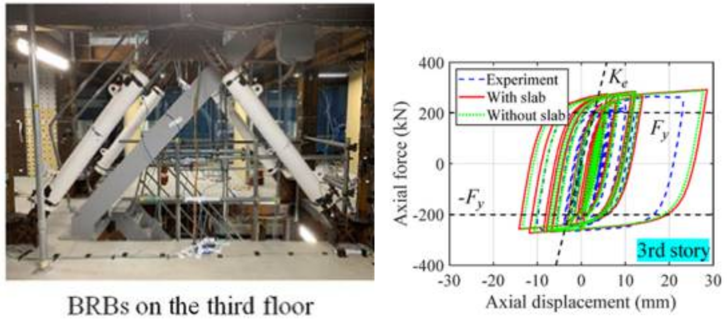
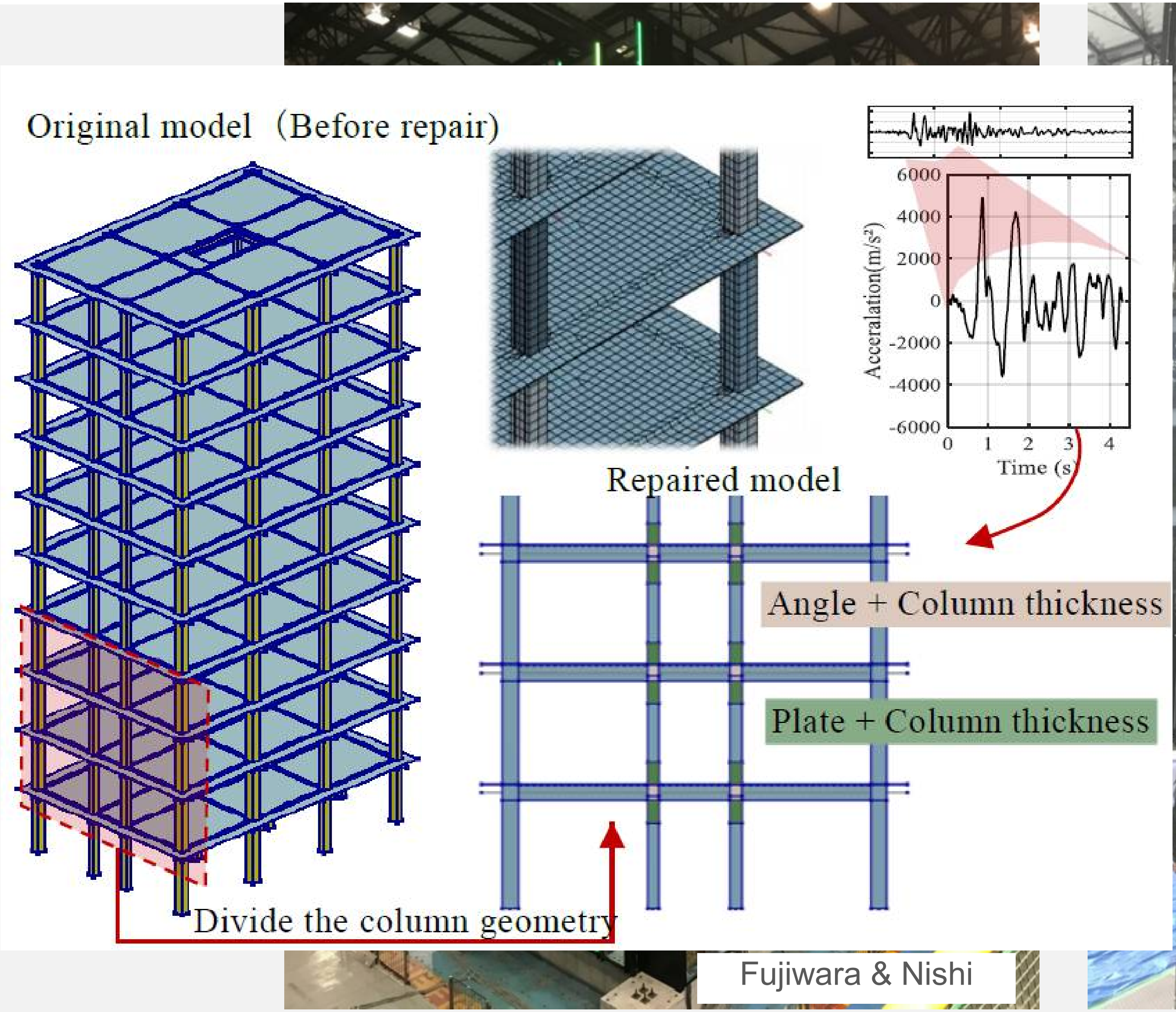


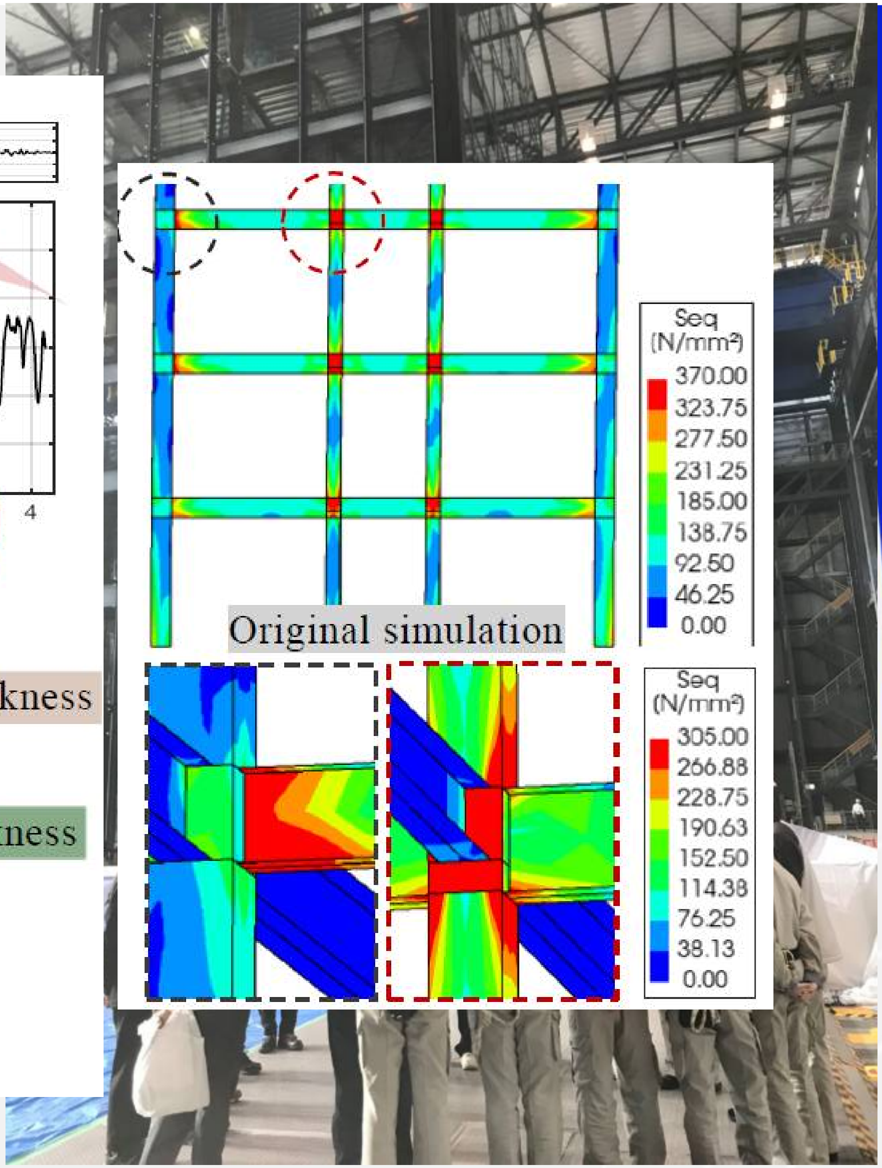
Fig. 18. Comparison of BRB responses in internal frame (B-Frame).

Fujiwara & Nishi

Cyclic pushover analysis for seismic response evaluation of a full-scale 10-story steel building tested on the E-Defense shake-table, Jin J, Nagae T, Asai T, Okazaki T, Li JH, Lignos DG, Chung YL, Fujiwara J, Kishida A, Kajiwara K, JOURNAL OF BUILDING ENGINEERING, Volume 96, 2024.11

Digital Twin (2026) Yan & Komatsu

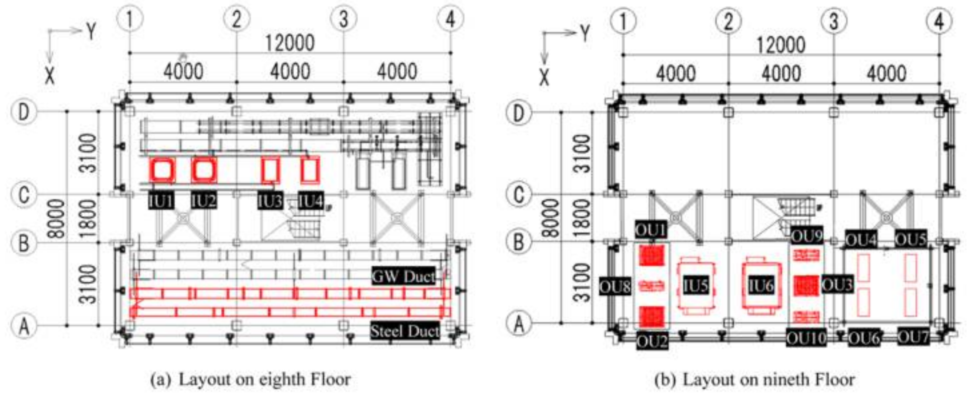




Numerical analysis of the seismic performance of a 10-story steel building with weak panel zones based on full-scale shake-table tests, T. Yan, J. Jin, J. Li, J. Fujiwara, A. Kishida, R. Nishi, K. Takaya, K. Kajiwara, T. Asai, T. Okazaki, T. Nagae, Journal of Building Engineering, Volume 111, 2025

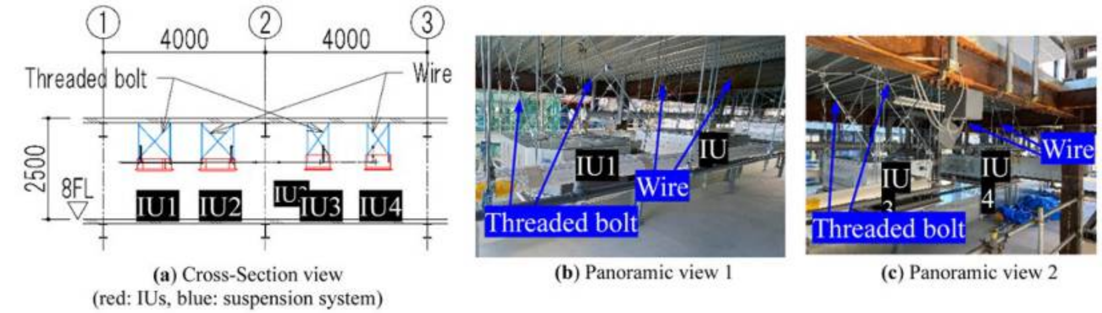
Seismic response and damage of nonstructural components observed via a full-scale shake table test on a 10-story steel building

Ryota Nishi [a,*], Jun Fujiwara [a], Koichi Kajiwara [a], Kunio Mizutani [b], Takuya Nagae [c]



(a) Layout on eighth Floor (b) Layout on nineth Floor

Fig. 3. Plan of the eighth and ninth floors.

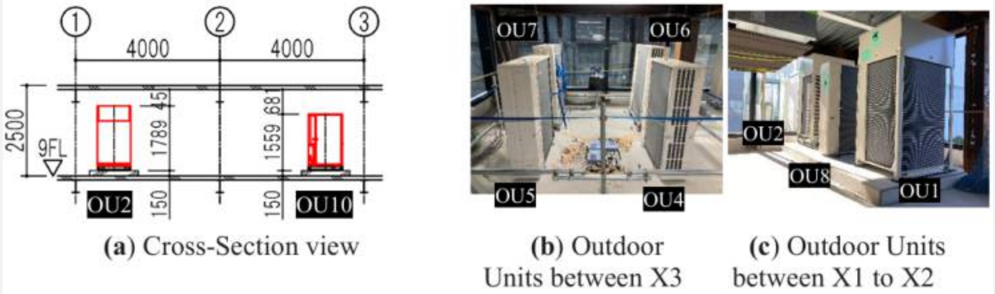


(a) Cross-Section view (red: IUs, blue: suspension system) (b) Panoramic view 1 (c) Panoramic view 2

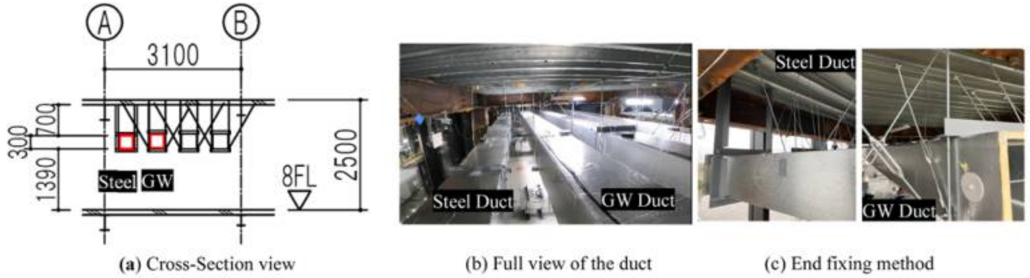
Fig. 4. Indoor units plan on eighth floor.

(a) Cross-Section view (b) Panoramic view 1 (c) Panoramic view 2

Fig. 5. Installation plan for indoor units on the ninth floor.

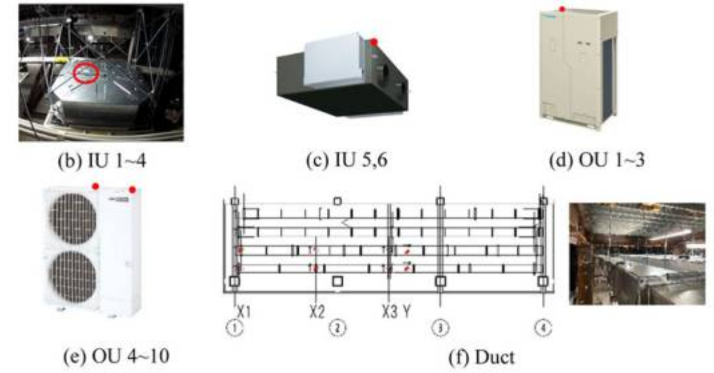


(a) Cross-Section view (b) Outdoor Units between X3 (c) Outdoor Units between X1 to X2



(a) Cross-Section view (b) Full view of the duct (c) End fixing method

Fig. 7. Plan and panoramic view of the ducts on the eighth floor.



(b) IU 1~4 (c) IU 5,6 (d) OU 1~3 (e) OU 4~10 (f) Duct

8. Installation plan of measurement devices.

Fig. 2. Panoramic view.

Seismic response and damage of nonstructural components observed via a full-scale shake table test on a 10-story steel building,
Ryota Nishi, Jun Fujiwara, Koichi Kajiwara, Kunio Mizutani, Takuya Nagae, Engineering Structures, Volume 354, 2026

150 Años UNI

CISMID 40 AÑOS

buildings

Takaya & Jin

excluded from the integral on the right side of the equation. As a result, Equation (1) in FEMA P-58 is converted to Equation (2) for loss evaluation in this study.

$$\lambda(DV) = \iiint G(DV|DS)\,dG(DS|EDP)dG(EDP|IM)d\lambda(IM) \quad (1)$$

$$\lambda(DV|IM) = \int G(DV|EDP)dG(EDP|IM) \quad (2)$$

Here, $G(X \mid Y)$ represents the probability of outcome X given the condition Y holds, and $\lambda(X)$ denotes the annual exceedance frequency of X.

PBEE Approach (2024)

Article

Practical Repair Cost Assessment of Steel Office Buildings with Diverse Beam-to-Column Connection Types in Japan

Kazuki Takaya [1], Jialiang Jin [1] and Takuya Nagae [2,*]

A two-dimensional frame model, interconnected by horizontal rigid links, was developed in the OpenSees platform [33] to represent the longitudinal frames of the prototype, as shown in Figure 2a. As shown in Figure 2b, beams and columns were modeled using elastic beam-column elements with nonlinear rotational springs at each end, following a concentrated plasticity approach. Panel zones were represented by pin-connected rigid elements arranged in a quadrilateral configuration, with a rotational spring modeled as a zero-length element at one of the corner joints. BRBs were modeled as individual truss elements with equivalent stiffness connecting two work-point nodes [34,35].

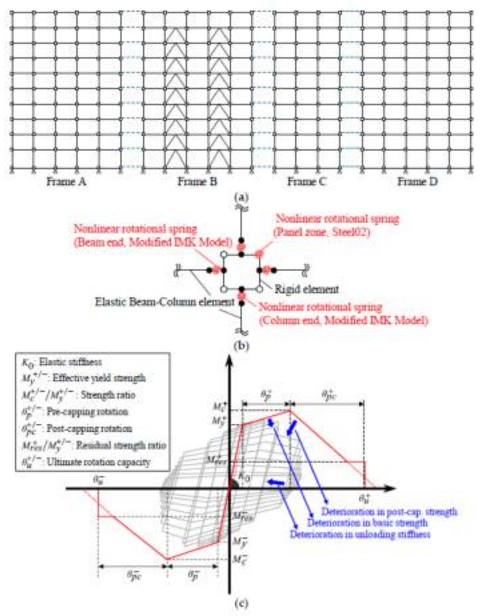


Figure 2. (a) Analytical model of the prototype; (b) beam-to-column connection model; (c) modified IMK model [15,36].

are continuously improving. However, loss functions developed to provide a more practical evaluation of repair costs compared to existing methods fail to replicate changes in deformation mechanisms caused by the performance of individual components. This highlights a knowledge gap regarding the gap between actual performance and the performance that can be represented in story loss functions. This study aims to quantitatively assess the impact of bea...

2.3. Story Loss Function

Fragility for damage and loss is selected based on the assumed conditions of the building's components, requiring prior acquisition of detailed component information. However, it is rare to have a component list and fragility database established for each component during the design phase of case studies. In this context, Papadopoulos et al. [8] developed a standardized set of structural components for typical buildings and proposed a story loss function to calculate the relationship between repair cost and EDP in advance, which can then be applied in repair cost assessments. This approach allows for rough repair cost estimates even when detailed component information is unavailable. The story loss function $C_r(EDP)$ classifies the structural type of the target building and its components, defining the relationship between the repair cost per 100 square meters of floor area and building response for each group, as approximated in Equation (10).

$$C_r(EDP) = C_{max} \cdot \left[\varepsilon \cdot \frac{EDP^{\alpha}}{\beta^{\alpha} + EDP^{\alpha}} + (1-\varepsilon) \cdot \frac{EDP^{\gamma}}{\delta^{\gamma} + EDP^{\gamma}} \right] \quad (10)$$

For repair cost assessment, the story loss function defined in Section 2.3 (Ref. [8]) is employed, enabling direct evaluation of repair costs based on the EDP through a function that substitutes fragility relationships for DS and DV. Additionally, to further assess repair costs for each earthquake intensity level, the probability function of earthquake intensity is excluded from the integral on the right side of the equation. As a result, Equation (1) in FEMA P-58 is converted to Equation (2) for loss evaluation in this study.

$$\lambda(DV) = \iiint G(DV|DS)\,dG(DS|EDP)dG(EDP|IM)d\lambda(IM) \quad (1)$$

$$\lambda(DV|IM) = \int G(DV|EDP)dG(EDP|IM) \quad (2)$$

Here, $G(X \mid Y)$ represents the probability of outcome X given the condition Y holds, and $\lambda(X)$ denotes the annual exceedance frequency of X.

2.2. Capacity Spectrum Method

In this study, the Capacity Spectrum Method (CSM) is used to determine the building responses. The CSM calculates the maximum seismic response of an equivalent single-degree-of-freedom (SDOF) system without the need for nonlinear time history analysis

related to seismic motion characteristics.

The performance curve for the equivalent SDOF system is derived from the results of static pushover analysis, as calculated using Equations (3) and (4):

Additionally, to calculate the response of each story fr... the equivalent SDOF system, the PFA response distribution ... the study by Ishihara et al. [28], and the maximum IDR dist... Mori et al. [29], using Equations (8) and (9), respectively.

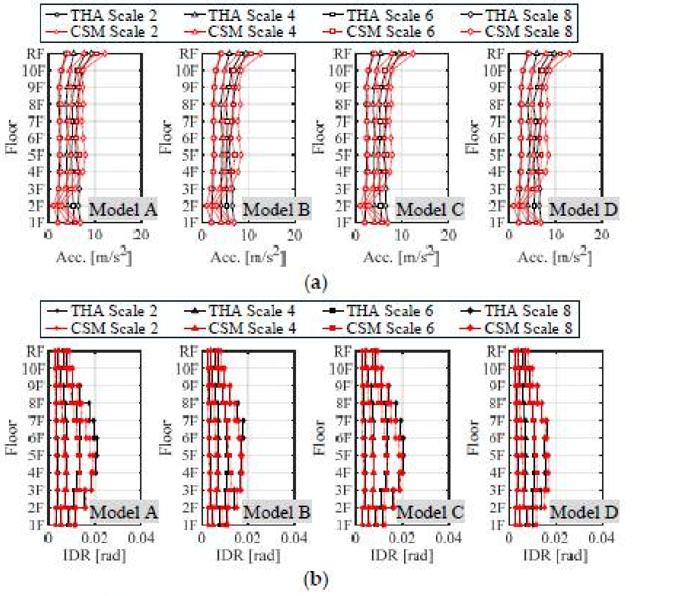
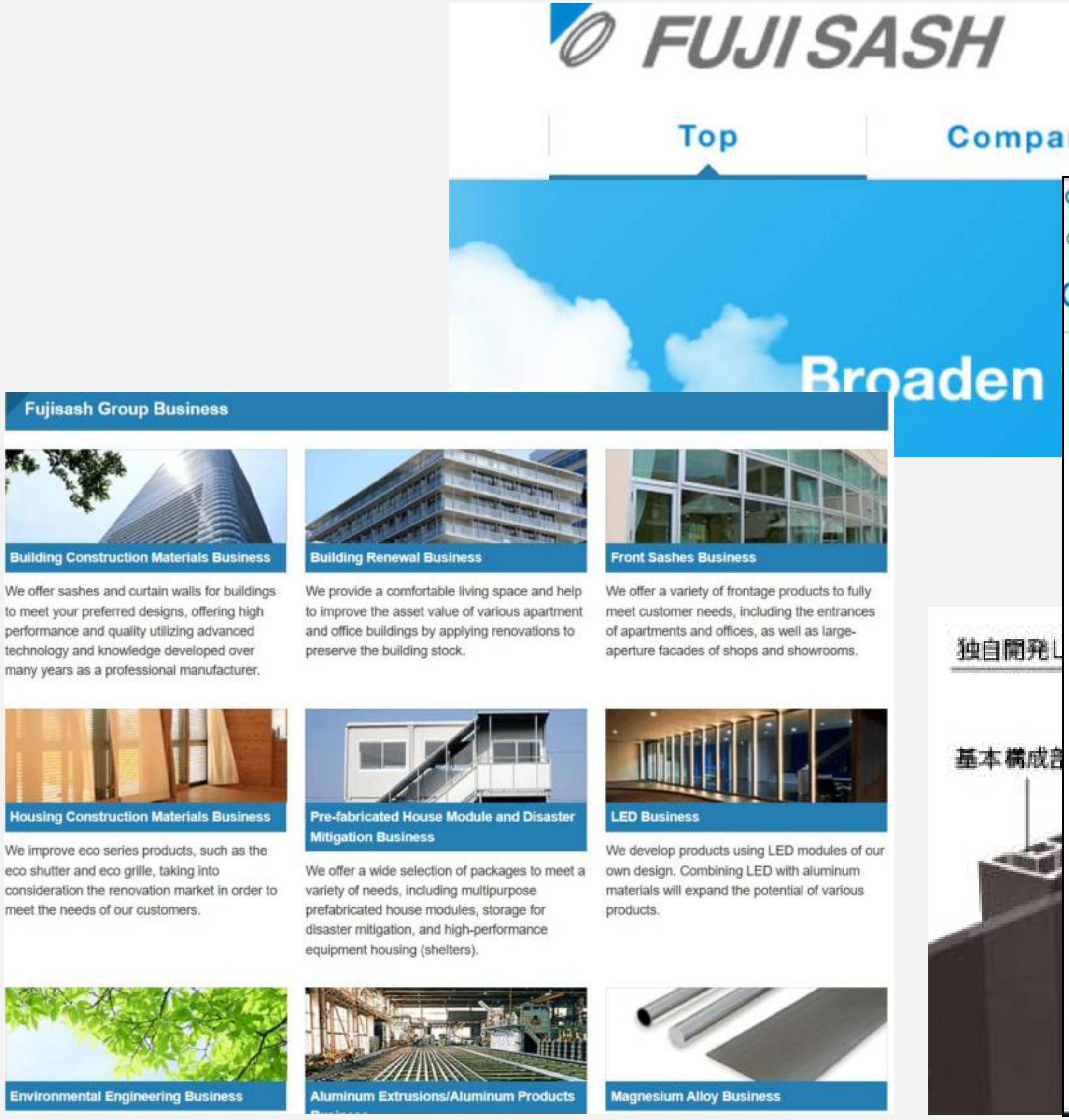
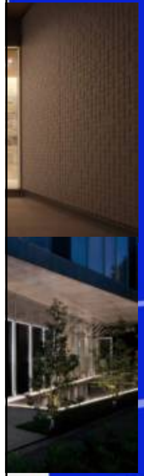


Figure 10. Median value of (a) PFA distribution and (b) maximum IDR distribution.

Business model based development with a curtain wall company





Assessment of a Curtain Wall System Used in High-Rise Buildings and Development of a Monitoring Method, S Toyao, T Nagae, J Chen, K Kajiwara, Y Kanzaki, YL Chung, International Conference in Commemoration of the 20th Anniversary of the 1999 Chi-Chi Earthquake, 2019.9

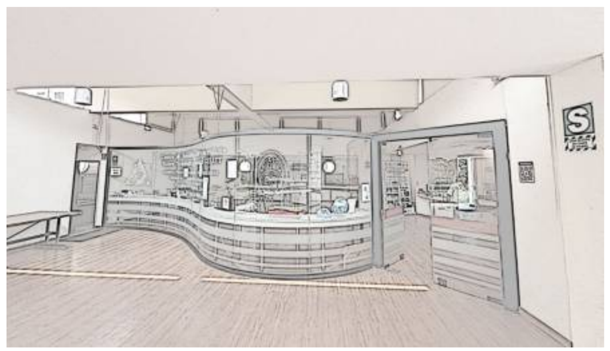
G4 Princ...

G4

En la Universidad de Nagoya, el 30 de julio (experimentando situaciones muy serias) →Operado y desplegado por CISMID 2026.3.12

CENEPRED
Centro Nacional de Estimación, Prevención y Reducción del Riesgo de Desastres

Details will be presented the day after tomorrow…



Muchas gracias

Instituciones colaboradoras

CHIBA UNIVERSITY
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AIST
TOHOKU UNIVERSITY
NAGOYA UNIVERSITY
CENEPRED
sedapal
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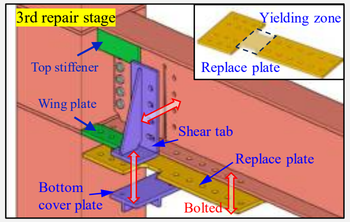
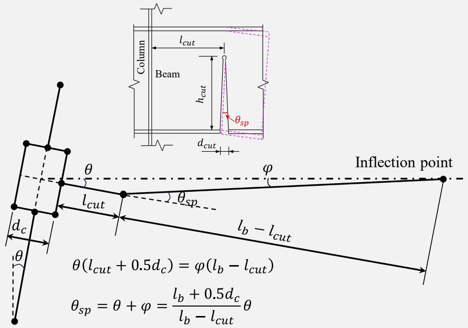
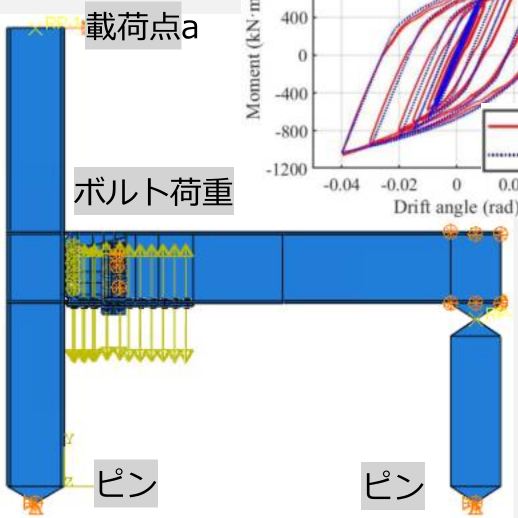
Institute of SCIENCE TOKYO
IGP Instituto Geofísico del Perú
TOKOHA

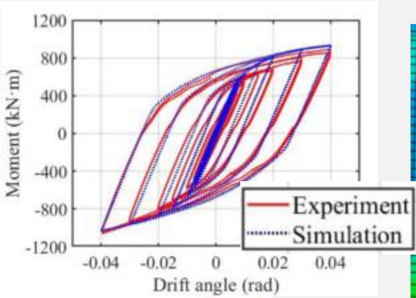
International joint actions for students

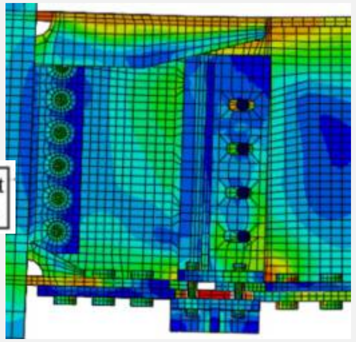
2024.9

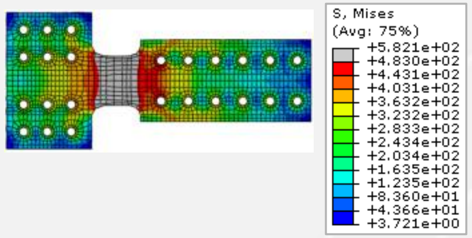












【台湾】　国立成功大学 (実験)・カリフォルニア大学（3次元有限要素法解析）　レジリエンス型梁端補修実験

Full-scale tests on resilient post-earthquake repair of steel beam-to-column connections, Yan TH, Chung YL, Jin JL, Lin KC, Komatsu Y, Nagae T, Journal of Building Engineering, Volume 108, 2025