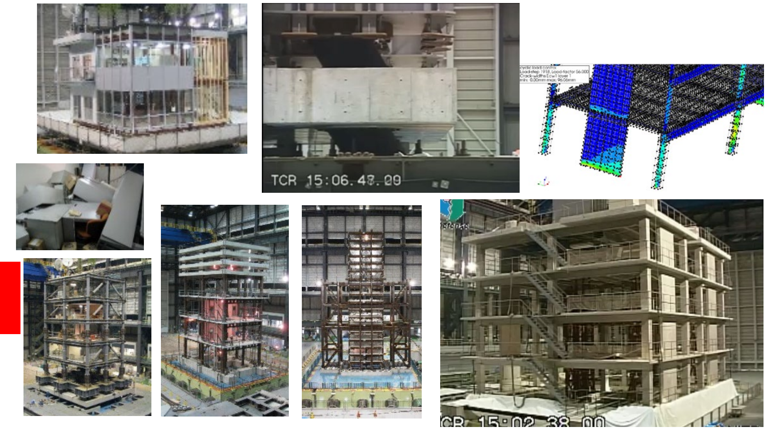
August 13, 2024 TJU

Comprehensive Seismic Performance Assessment by Various Shaking Table Tests

Takuya Nagae
Nagoya University

NagaeTakuya (長江拓也)

Associate Professor
Nagoya University



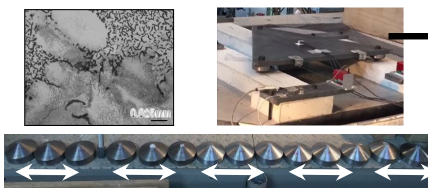
NIED Hyogo EERC (E-Defense) 2006-2014

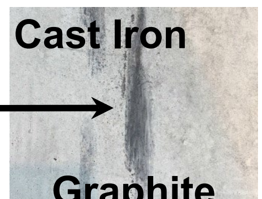
Senior Researcher

Eight test series were completed by him.
→ The MEXT Young Scientists' Prize

High-Rise Building Assessment
Reinforced Concrete Structure Verification

Element Investigation



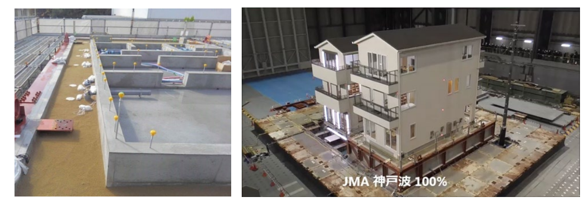


Lubrication

Damage Mitigation

2015.12

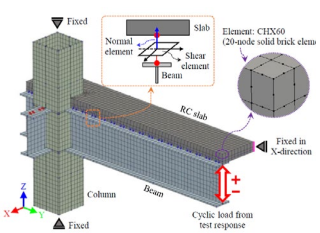
Base Sliding



MEXT Metropolitan PJ 2019.2

1. Low-Cost High-Performance N

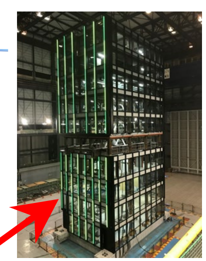
2. Low-rise Performance with Soil-Foundation

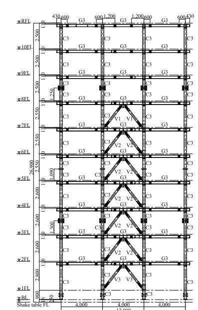


3D Solid FEM

2018.12

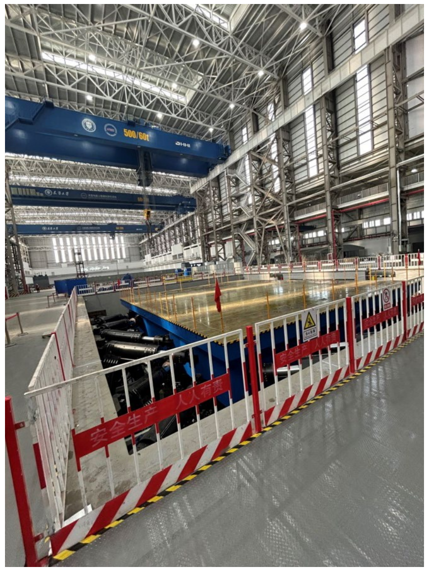
Curtain Wall Sensing System





3. Numerical Analysis and Sensing Technology

New collaboration based on NFEES, Tianjin University



March 13-14, 2024

Topics

1. High-rise building by substructure testing
2. Sensing technology with the industrial
3. Soil structure interaction highly inelastic
4. Detailed simulation with the industrial

Topics

1. High-rise building by substructure testing
2. Sensing technology with the industrial
3. Soil structure interaction highly inelastic
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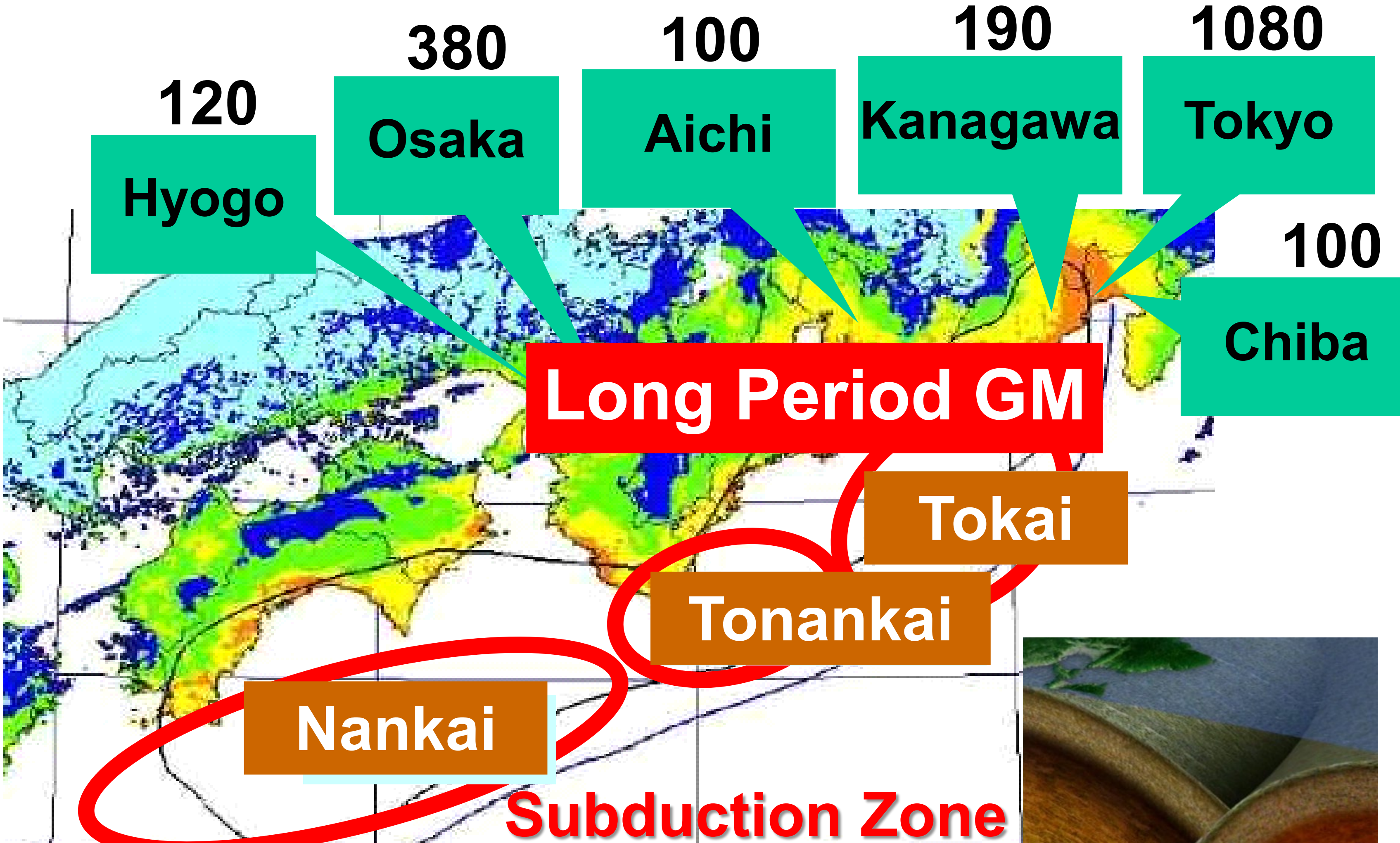
Japan's National Issue

80% of more than 2500 high-rise buildings



Inside Fragility

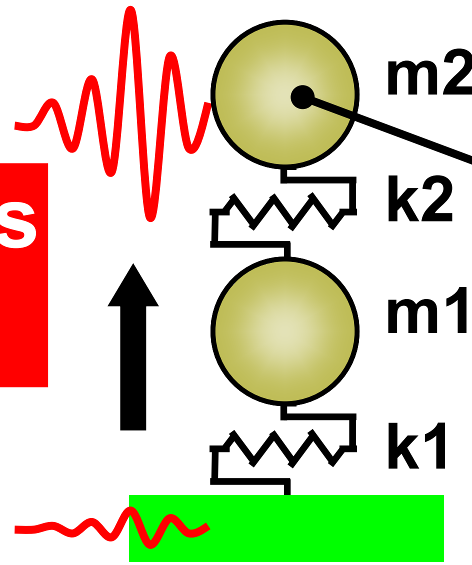
Not prepared

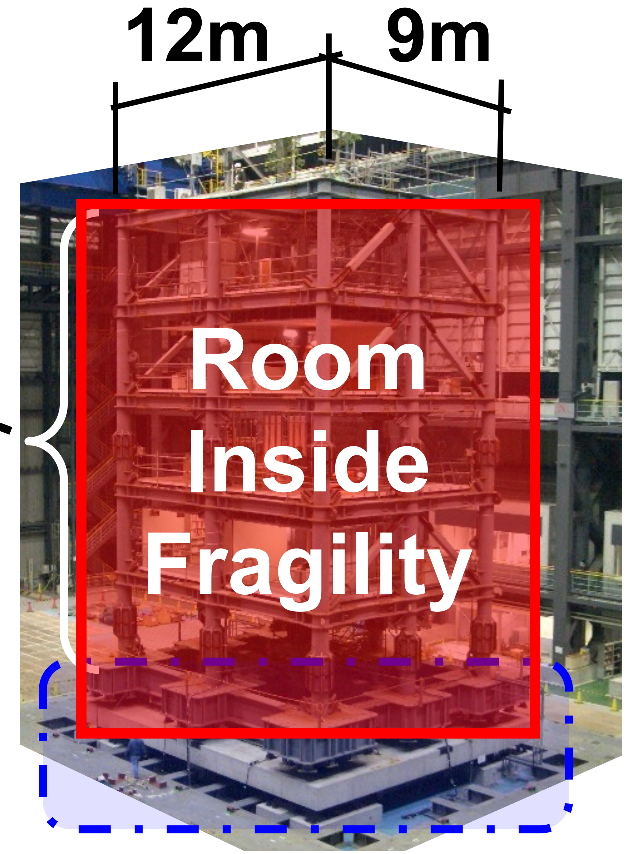
Prepared

Substructure

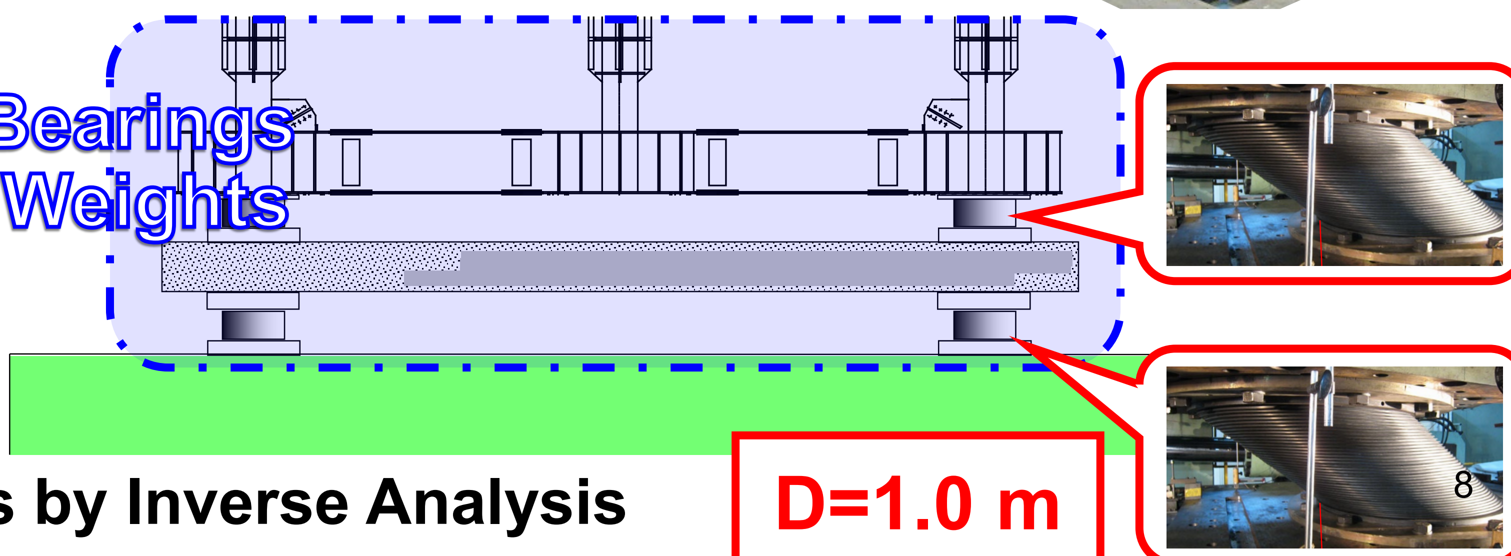
2007 and 2008

Large Amplitudes
Long Duration





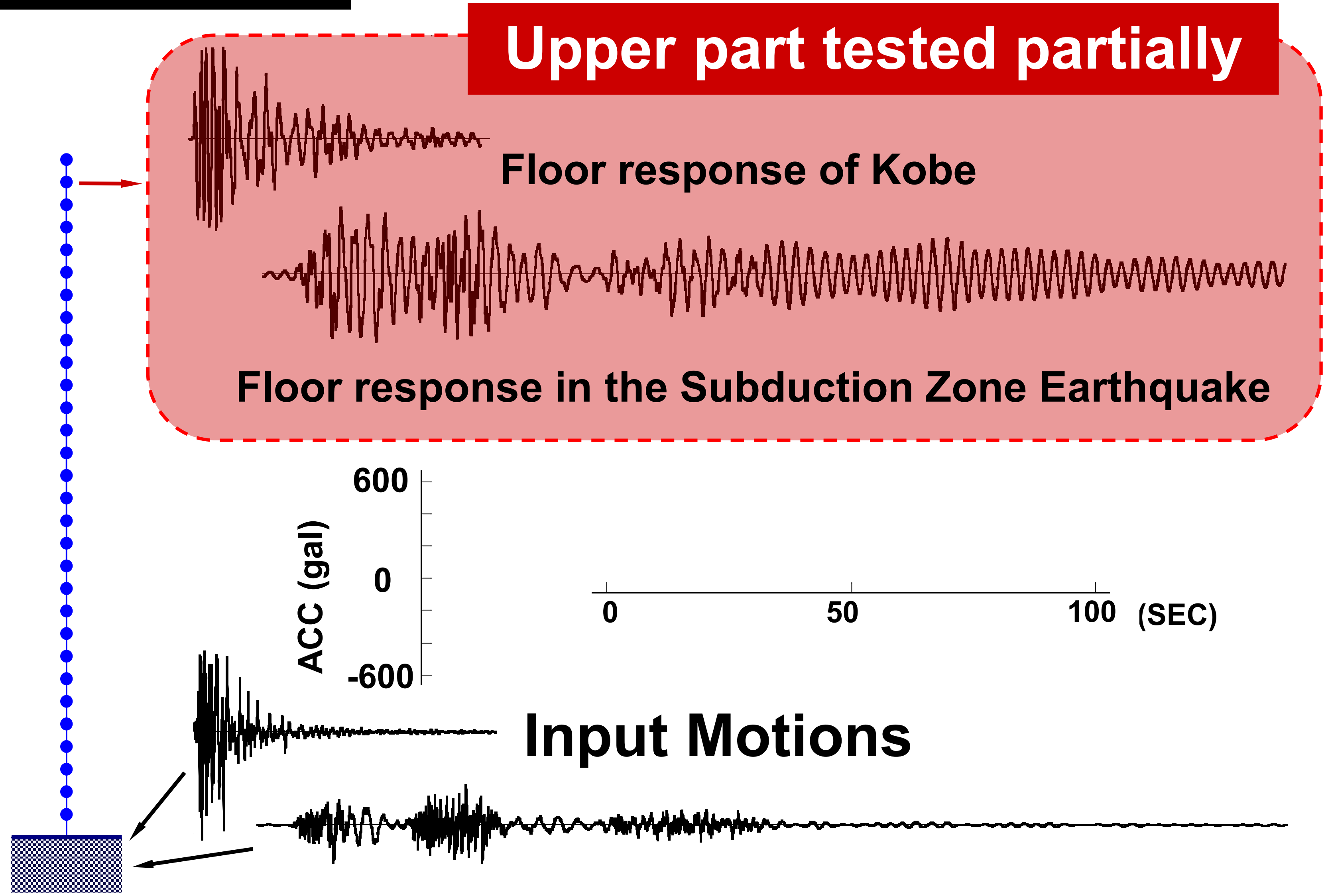
Rubber Bearings
RC Slab Weights



Inputs by Inverse Analysis

D=1.0 m

Concept



Stick model of the High-rise

Long duration（2007, 2008, Upper part）

Office

Not just down time but casualties

文部科学省 MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

2007-2011

MEXT national project

Existing buildings in 60's, 70's, 80's

研究運営委員会

Supervising Committee

【目的】

　研究の進展及び成果の展開などプロジェクト全体を睥睨し、適切な助言を与えるとともに、研究コミュニティ間の連携を推進する。

【メンバー】

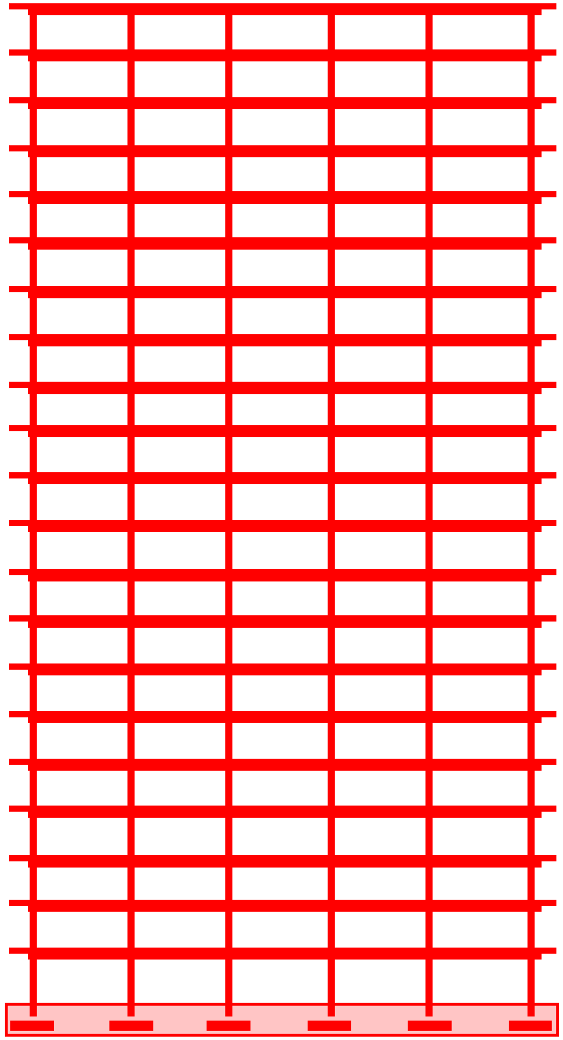
委員長：和田章 (東京工大)
委　員：飯場正紀(建研)，壁谷澤寿海(東大)，寺本隆幸(東京理科大)，長澤泰(工学院大)，濱田政則(早大)，藤田聡(東京電機大)，堀宗朗(東大)

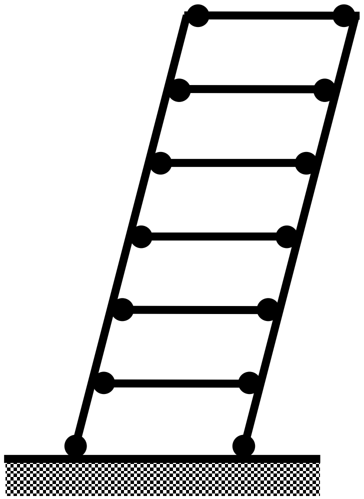
【開催歴】

平成１９年９月５日、
平成２０年９月２９日、

・結果の評価、展開もの検討など

Complete mechanism of beam hinging



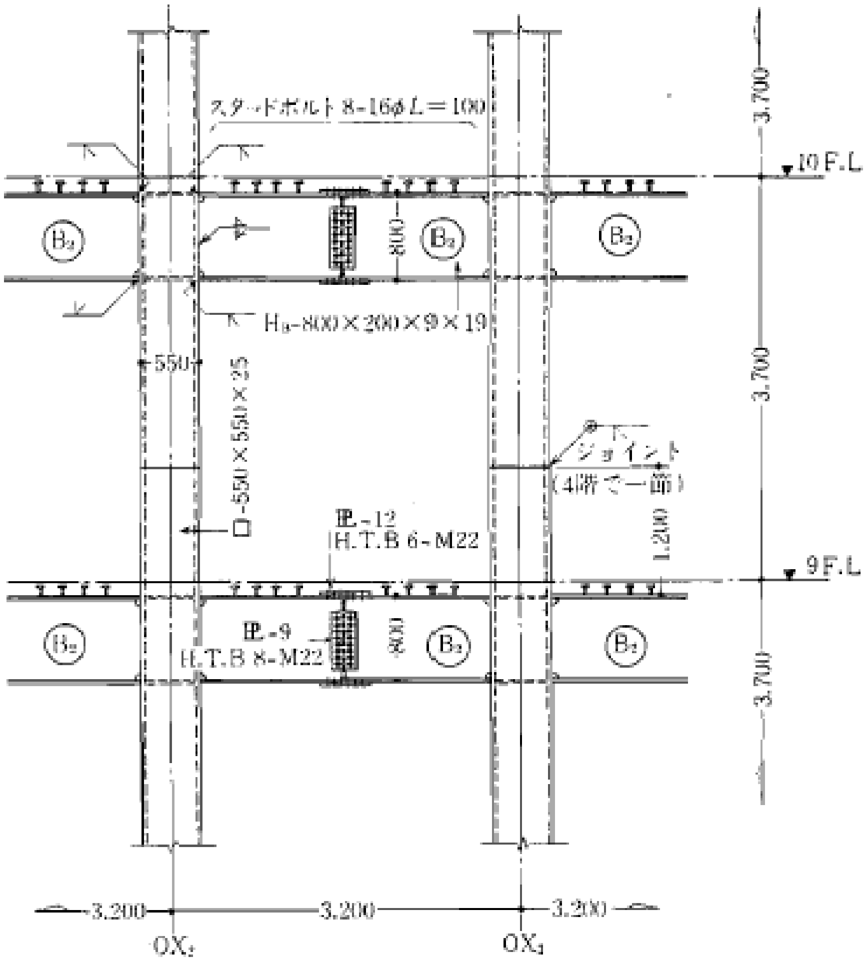


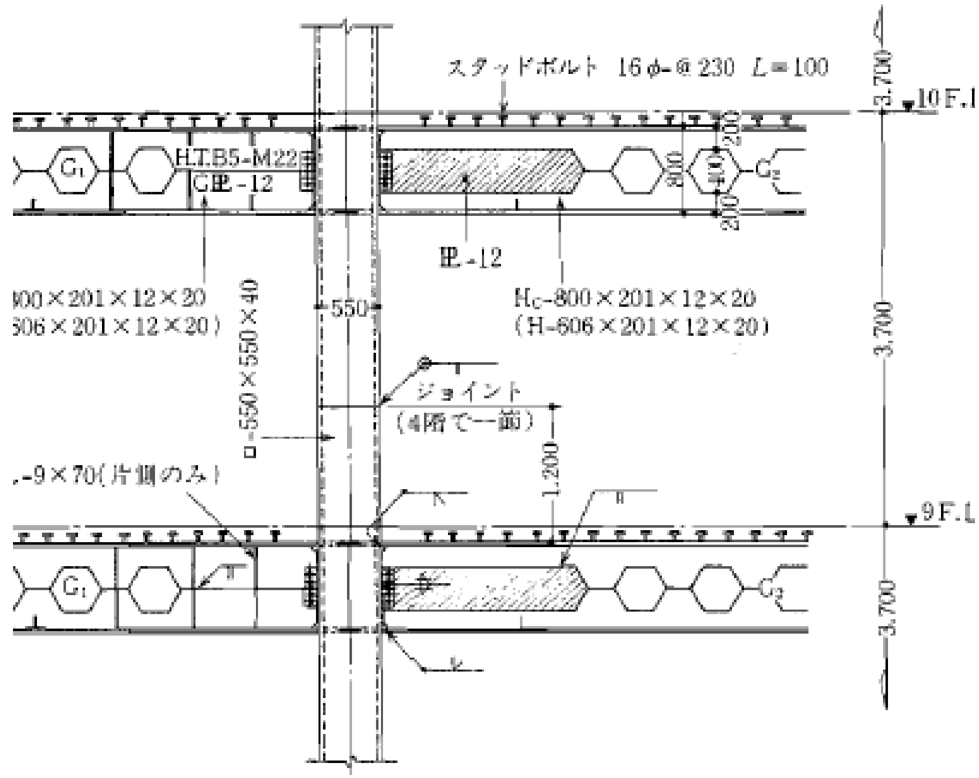
超高層設計の基本理念
弾性範囲を超える弾塑性応答
特定層への変形集中回避

Seismic loading（2009, Beam hinging）

video

Connections details not allowed now



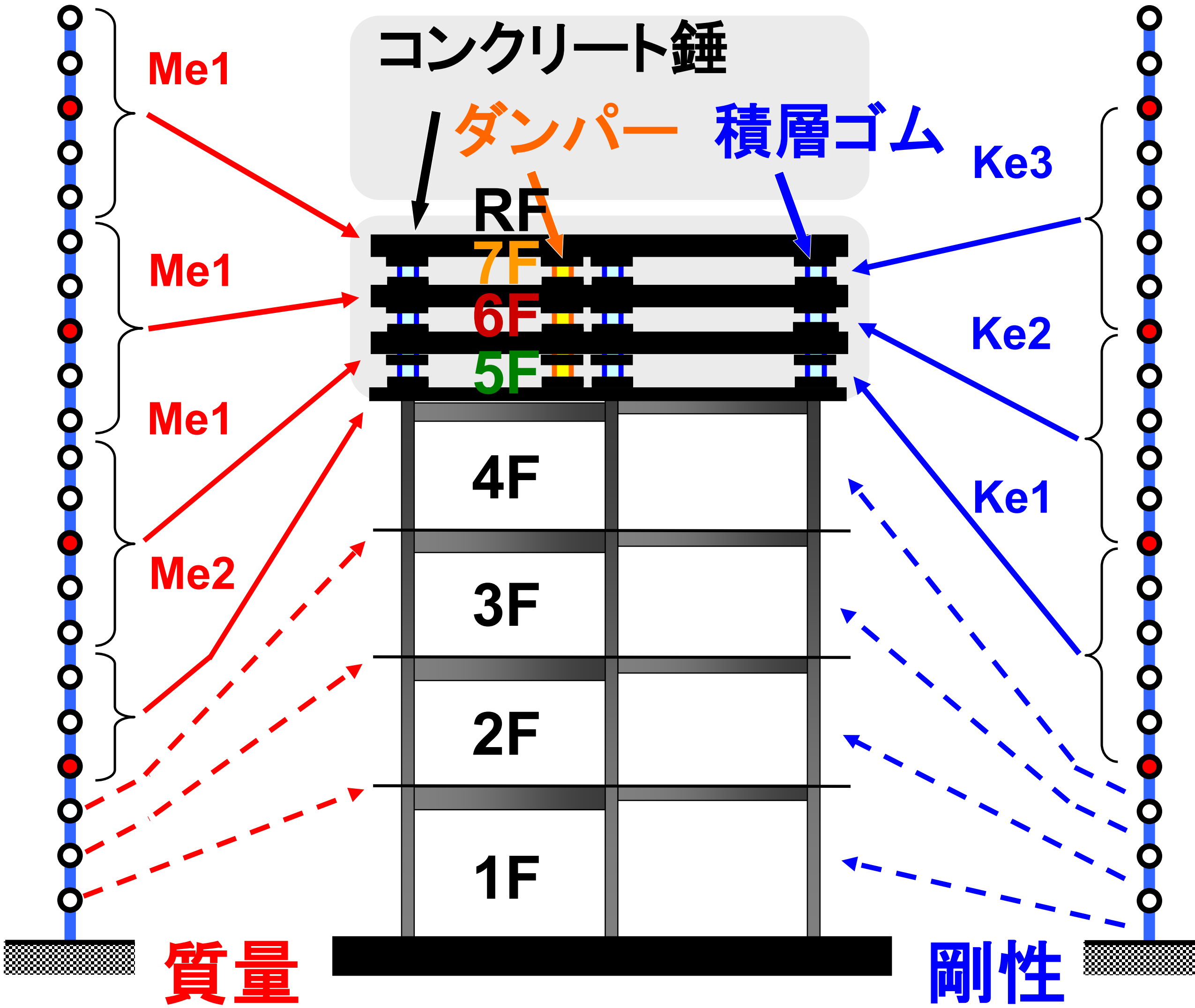


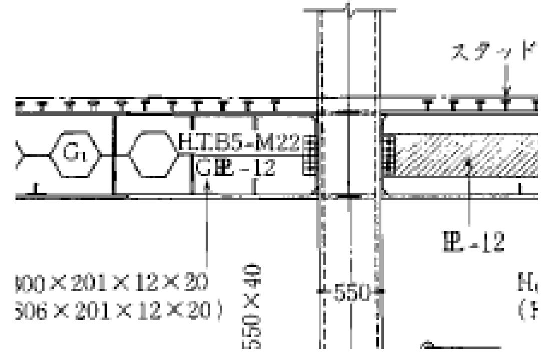
1970年代の設計資料

Weak web bolt, Access hole, Low quality

Real connections

1100 ton→ Total weight limit





RC floor slab, anti-symmetric M-distribution

D13@200
D10@100

Studs 19ϕL=80@150

Decks

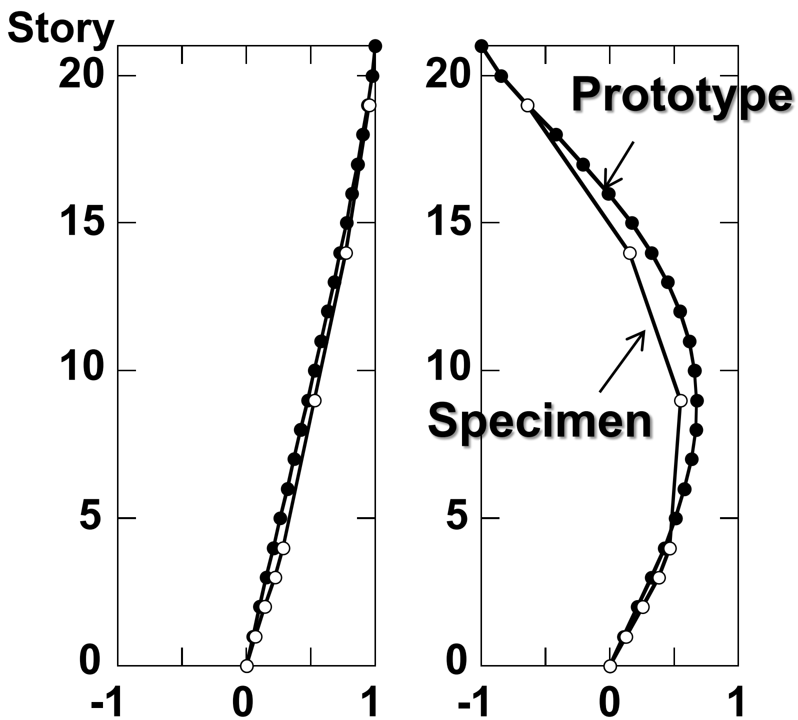
Studs

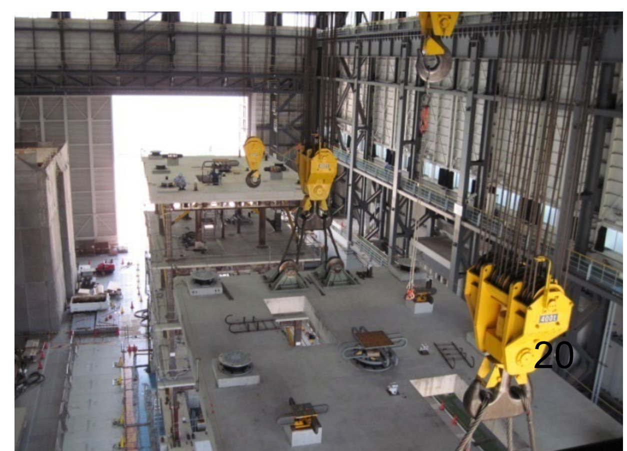
Concrete

Welding

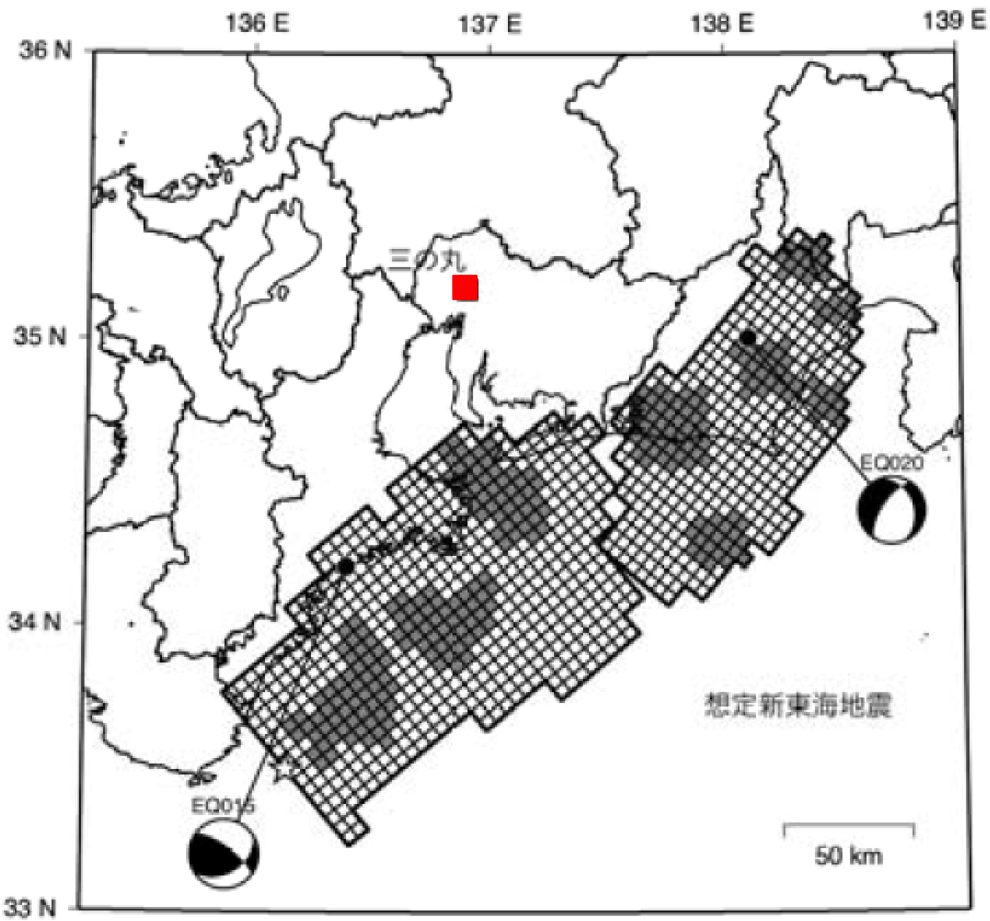
2007

Real time scale→Input ground motion





Long Period Ground Motion



計算地点と想定新東海地震の断層モデルおよび観測された地震の震央位置

（中部地方整備局資料）

東海･東南海地震

名古屋三の丸波 2002

免震工法による耐震改修

中部地方整備局
名古屋第2地方合同庁舎 2007

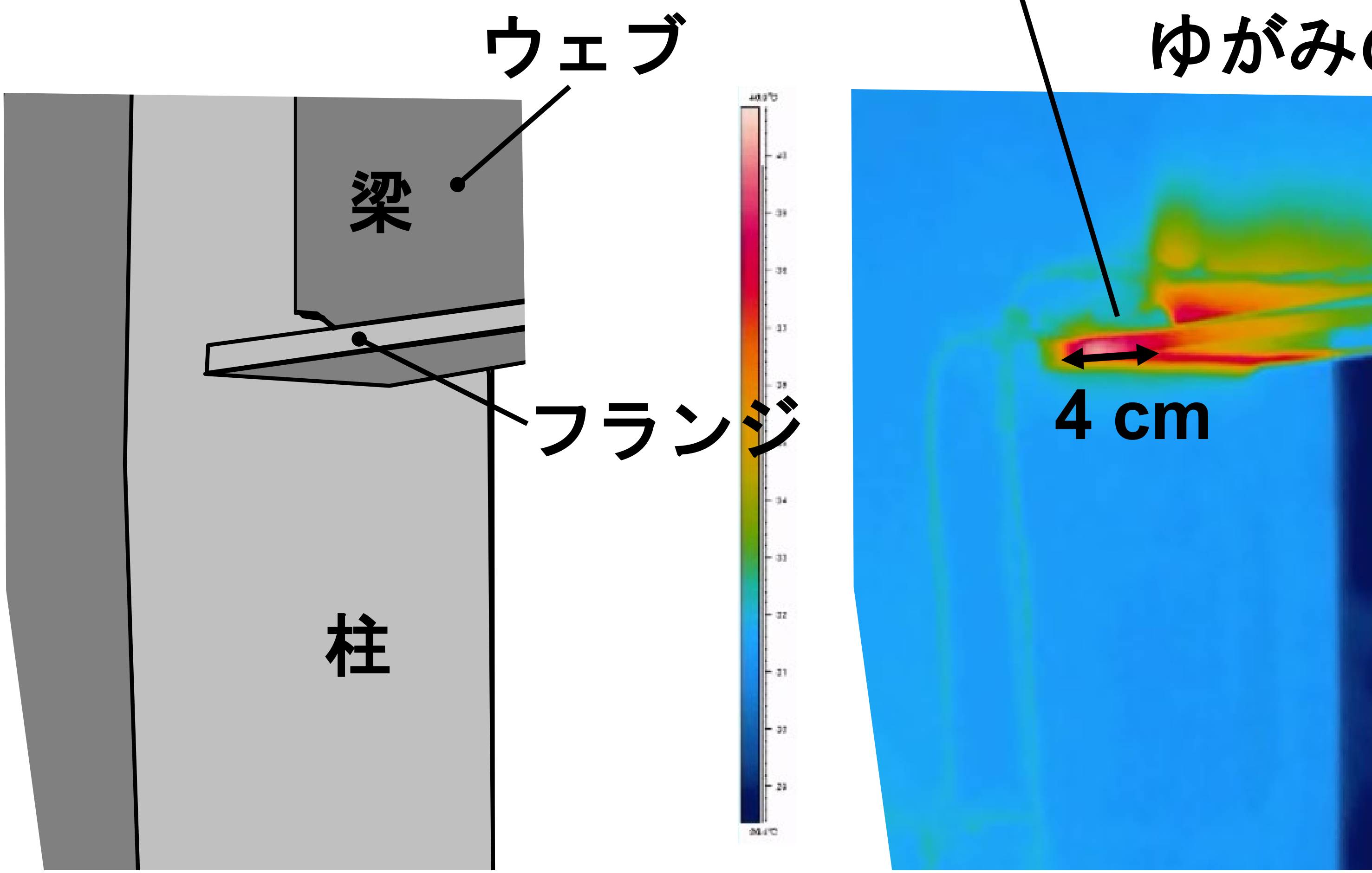
愛知県
愛知県庁 本庁舎 2009

名古屋市
名古屋市役所 本庁舎 2010

Strain concentration

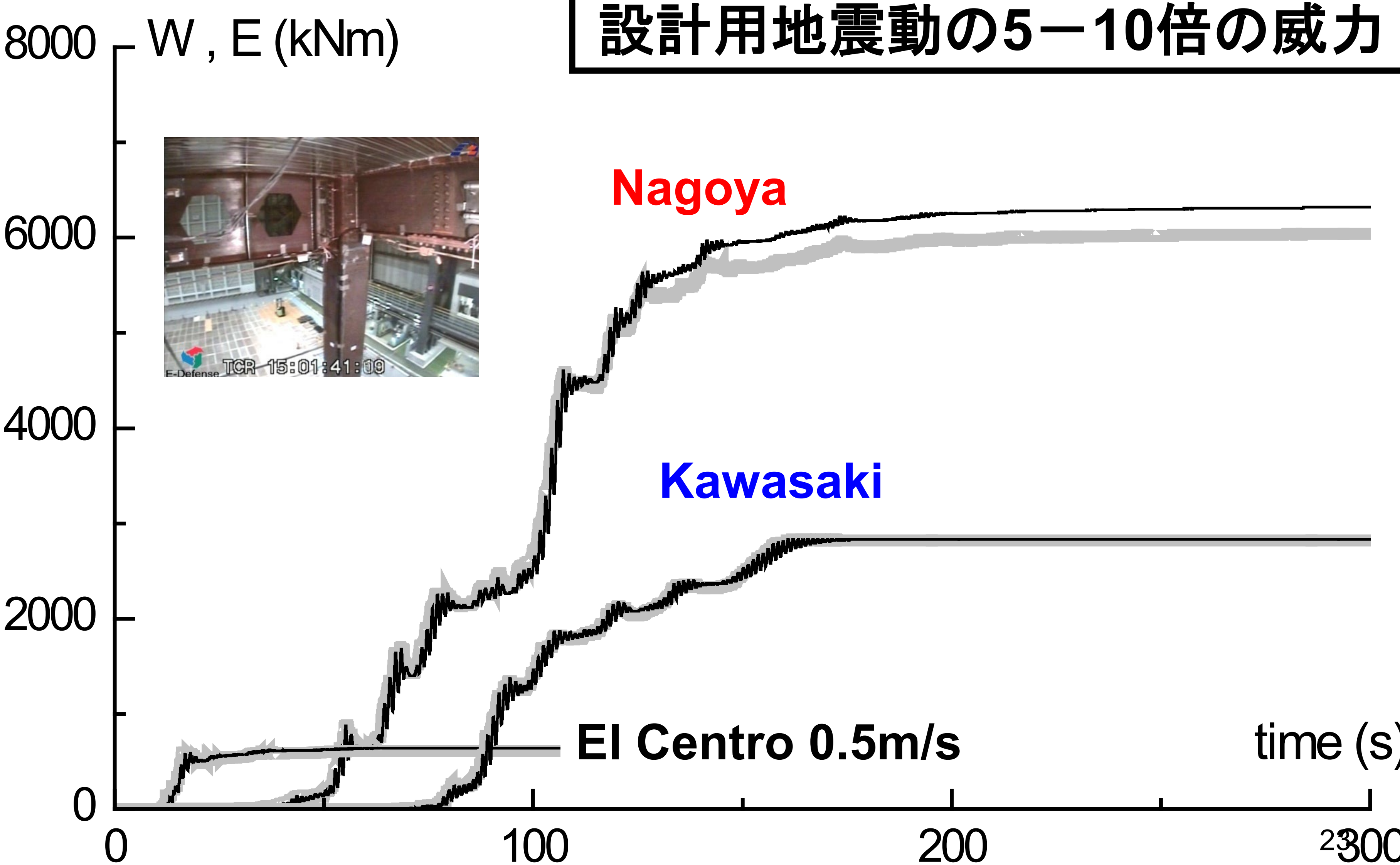
梁の根元のごく一部分が温度上昇
>> 地震エネルギーを吸収

エネルギー >>
ゆがみの蓄積 >>
熱

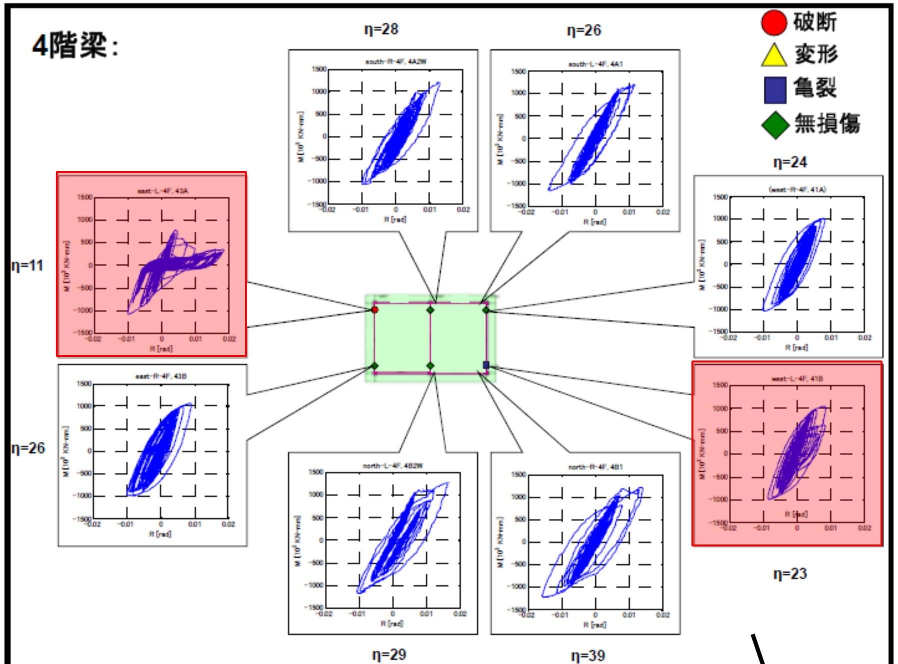


Total input energy in a long duration

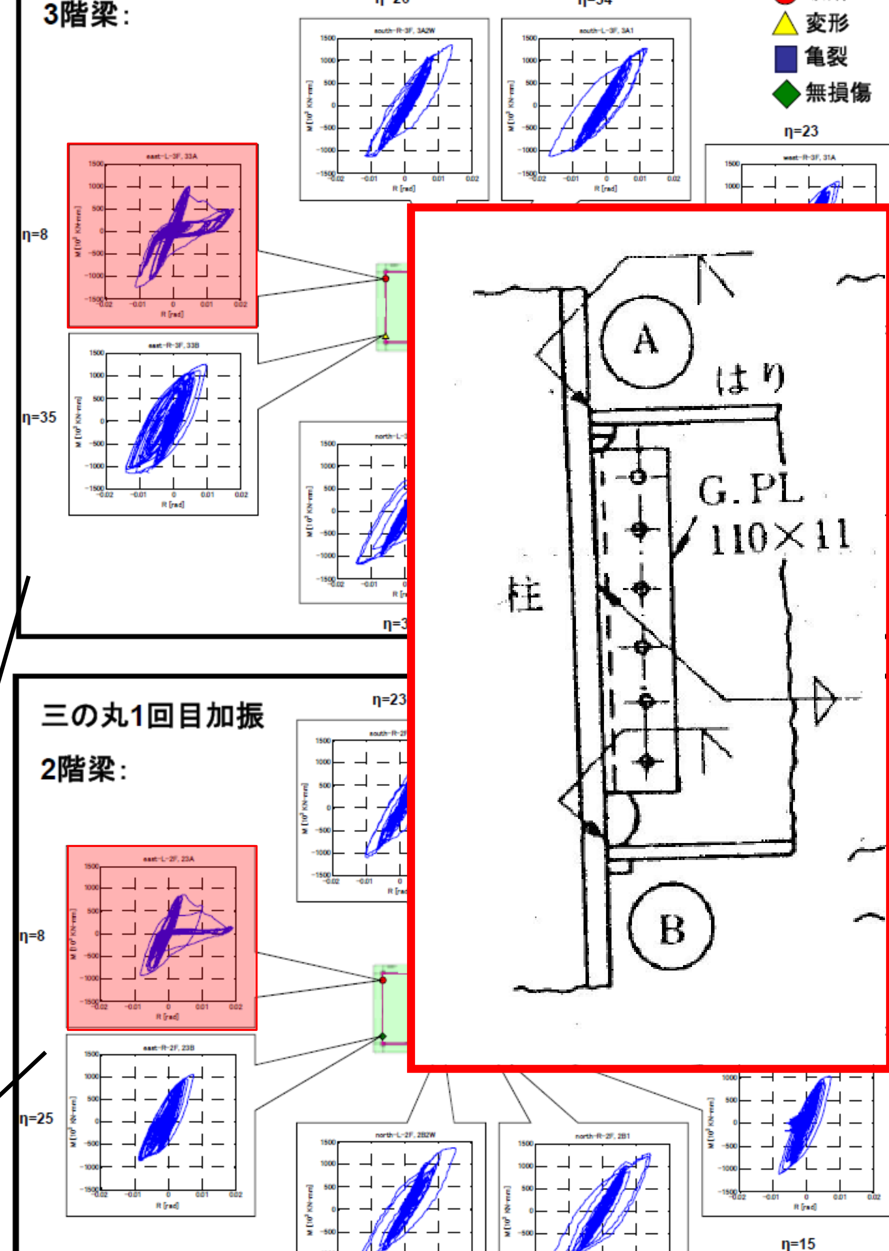
設計用地震動の5－10倍の威力

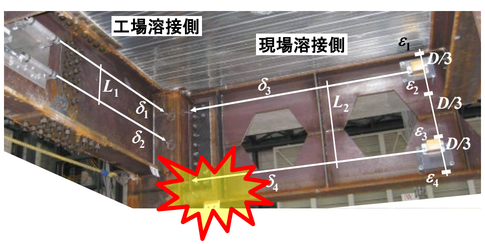


Bottom flange

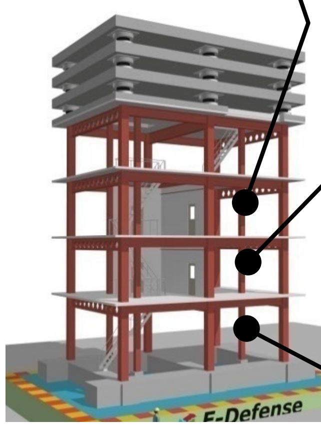


名古屋·三の丸波





計測方法



Poor connection details showed low deformation capacity

National reactions

2009. 1 Mainichi

毎 日 新 聞　〔第３種郵便物認可〕

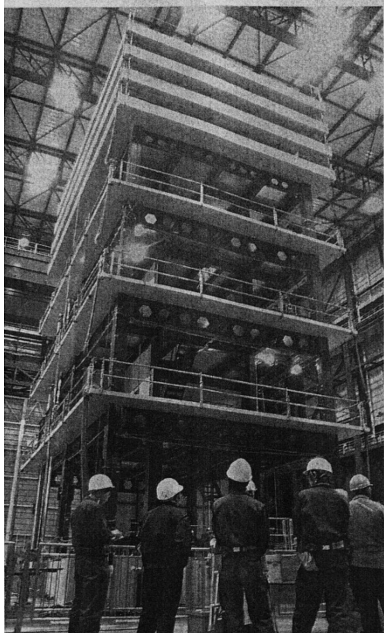
科学

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造られた実験用ビル＝兵庫県三木市の防災科学技術研究所で

◆21階建てを想定

実験は、独立行政法人防災科学技術研究所の兵庫耐震工学研究センター（兵庫県三木市）で行われた。実物大のビルを上下左右に揺らせる国内唯一の三次元震動台「E―ディフェンス」が使われた。

震動台の上に建設費約8000万円をかけ、鉄骨4階建てのビルを建てた。屋上にゴムを挟んだ4枚のコンクリート板（重さ約700㌧）の重りを乗せ、高さ80㍍、21階建ての超高層ビルの下部を模した。ビルの高さは重りも含め21㍍に達する。

次に震動台を揺らし、東海地震が起きた場合、首都圏が見舞われると想定される揺れを2分間、ビルに加えた。コンクリートの床がひび割れ、内壁がはがれ落ちた。

さらに強い揺れとして、東海地震と東南海地震が同時に発生した場合に、名古屋市の中心部で想定される揺れを5分30秒間加えた。ビルはしなるように揺れ、柱とはりの溶接部分が各階で割れてボルトだけでつながっている状態になった。

防災科研によると、実験に使ったビルの強度は、実際に存在する高層ビルの平均程度。これより弱いビルや、部分的に壊れやすいビルもあるという。

同研究所の長江拓也研究員(33)は「実験のような被害が出れば大規模な補修が必要だ。ビルは長期間使えなくなり、経済的損失は大きい。弱いビルなら、実験より小さい地震動で被害が出る恐れもある」と分析する。

震動実験で破断したはり。写真の左下から右上に向かって亀裂が入っている

◆設計に考慮されず

超高層ビルは1960年代に建設が始まった。研究者の一部は当時から、長周期地震動の影響を心配していた。しかし、従来の設計では考慮されてこなかった。

理由は、強い長周期の揺れをもたらすような地震波の記録が、00年ごろまでほとんどなかったことだ。ビルの設計に当たっては、過去に起きた大地震の地震波を使い、ビルがどう揺れるかを模擬計算する。使われてきたのは、1940年に米国西海岸のエルセントロで観測された地震波や、68年の十勝沖地震の波などだ。いずれも長周期の揺れはあまり強くなかった。

大手ゼネコンで超高層ビルの設計に携わった北村春幸・東京理科大教授(56)は「設計に使える地震波がなく、長周期地震動の影響は計算できなかった。影響は建設後も検証されてこなかった」と説明する。

長江研究員は「実験で、長周期地震動の影響が確認できた。既存の超高層ビルの設計を確認し、弱い場合は揺れを小さくする制震ダンパーの設置などの対策を考えるべきだ」と指摘する。今後は、具体的にどのような補強をすれば、被害が小さくできるかを検証する実験に取り組むという。

2秒以上かけ1往復の揺れ

地震の波は、小刻みな速い揺れや、ゆっくりした揺れが交じってできている。揺れが1往復する時間を「周期」と呼ぶ。約2秒以上の周期の揺れが「長周期地震動」だ。

一般に、周期が短い揺れは低い建物を揺らしやすく、長い揺れは高い建物を揺らしやすい。民家などに被害を出すのは周期が0・1秒程度の揺れだ。周期1秒で10階建て、2秒では20階建てなど、周期の秒数に10をかけると、被害の出やすい建物の階数が大まかに分かるとされる。

超高層ビルでは、長周期の揺れが被害の主因になるとみられてきた。他にも、橋や石油タンクなど大規模な構造物は長周期の影響を受けやすい。

長周期の揺れは、主に大規模地震で生じる。短周期に比べて遠くまで伝わりやすい。首都圏や名古屋、大阪など平野部の軟らかい地盤の堆積層で増幅され、大きな揺れになりやすいのも特徴だ。

1985年のメキシコ地震（マグニチュード〈M〉8・1）では、震源から約350㌔離れたメキシコ市で21階建てのビルが倒壊した。日本では、03年の十勝沖地震（M8・0）の際に、北海道苫小牧市の石油タンク群が大きく揺れ、火災が起きた。04年の中越地震（M6・8）では、東京・六本木の超高層ビルでエレベーターのケーブルが切れるなど、震源から遠く離れた場所でも被害が出た。

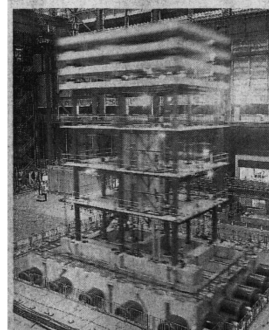
2009. 1 Asahi

日 新 聞　第3種郵便物認可

どうする長周期地震動

全国に2千数百棟ある、高さ60㍍以上の超高層ビル。設計当時は十分解明されていなかった長周期地震動の影響で、大きな被害が出かねないことがわかってきた。阪神大震災で超高層ビルの被害は目立たなかったが、東南海、南海地震などの巨大地震を乗り切れるのか。すでに補強工事など具体的な動きが出始めている。（添田孝史、田之畑仁）

超高層ビル 補強へ動き



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

実験、「切れぬはず」が切れた

「衝撃的だった。通常の揺れでは、まず切れないはずなのに目の前で切れた」。防災科学技術研究所（防災科研）の長江拓也主任研究員は昨年3月、震動実験施設「Eディフェンス」（兵庫県三木市）で超高層のモデルを長周期地震動で揺らす実験を行った。21階建てビル（高さ80㍍）とほぼ同じ揺れ方をする鉄骨ビル（同21㍍）を造り、東海地震の時に名古屋市で想定される地震動で揺らした。

巨大な鉄の骨組みが、静かにゆっくりと揺れ始めた。5秒……10秒……。時間がたつにつれて、揺れはさらに大きくなっていく。

建物が揺れ始めておよそ30秒後、柱と梁を溶接した接合部分がパックリとちぎれた。大規模な補修が必要になるほどの被害だ。

長江さんは「揺れが長時間繰り返されることで接合部分に何度も力がかかり、金属疲労に似た現象が起きたのではないか」と分析する。

「最大振幅4メートル、6分」分析も

超高層への影響が心配される長周期地震動は、ゆったりした揺れが何分間も続くのが特徴だ。マグニチュード（M）8級の巨大地震で引き起こされやすく、三大都市圏など分厚い堆積層がある平野部で揺れが大きくなる。03年の十勝沖地震では、北海道苫小牧市で石油タンクが壊れて火災を起こした。

入倉孝次郎・愛知工大客員教授は「十勝沖地震で実際に揺れのデータが集まり、関係者も本気で取り組まざるを得なくなった。それまではシミュレーション研究が中心で、警告が十分には信用してもらえなかった」と言う。

日本建築学会は04年に調査委員会を立ち上げ、100㍍以上の超高層24棟の揺れを分析、07年12月に報告書をまとめた。安全性はおおむね保たれていた。ただ、南海地震が起きた時に大阪市で想定される揺れで分析すると、設計基準を超えて変形するビルが複数あった。最上階では最大振幅が4㍍近くになる揺れが、6分以上続くビルもあった。

報告書は「長周期地震動による入力エネルギーは、これまで設計に用いてきた地震動を大幅に上回る可能性があるから、個々の建物で安全性の検討をすることが望ましい」と提言した。

東京・大阪で調査・工事続々

影響調査や補強工事の動きも出てきた。

大阪府は昨年12月から、庁舎移転を検討中の「大阪ワールドトレードセンタービルディング」（WTC）（95年完成、大阪市）で、長周期地震動の影響調査を始めた。高さは256㍍で、日本で2番目に高い。

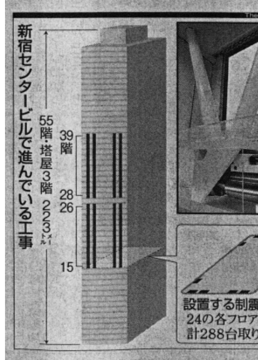
大阪WTCは当時、長周期地震動を考慮していなかった。このビルは、高さや構造から約5・3～5・8秒周期で最も揺れやすい。阪神大震災後、大阪平野は5秒前後の周期の地震動が大きくなりやすいことがわかった。WTCは共振しやすく要注意だ。

南海地震などを想定したときにビルがどう揺れるかを計算し、損傷や対策費用がどの程度か、エレベーターは壊れないかなどを調べる。東京都庁（243㍍、91年完成）も検討に入った。

新宿センタービル（高さ223㍍）は昨年10月、制震装置を取り付ける工事を始めた。大成建設の計算では、東海地震で、構造部分などの被害と修理中に賃貸収入が無くなることで、100億円規模の損害が出る。補強に数十億円かけても「安上がり」だという。

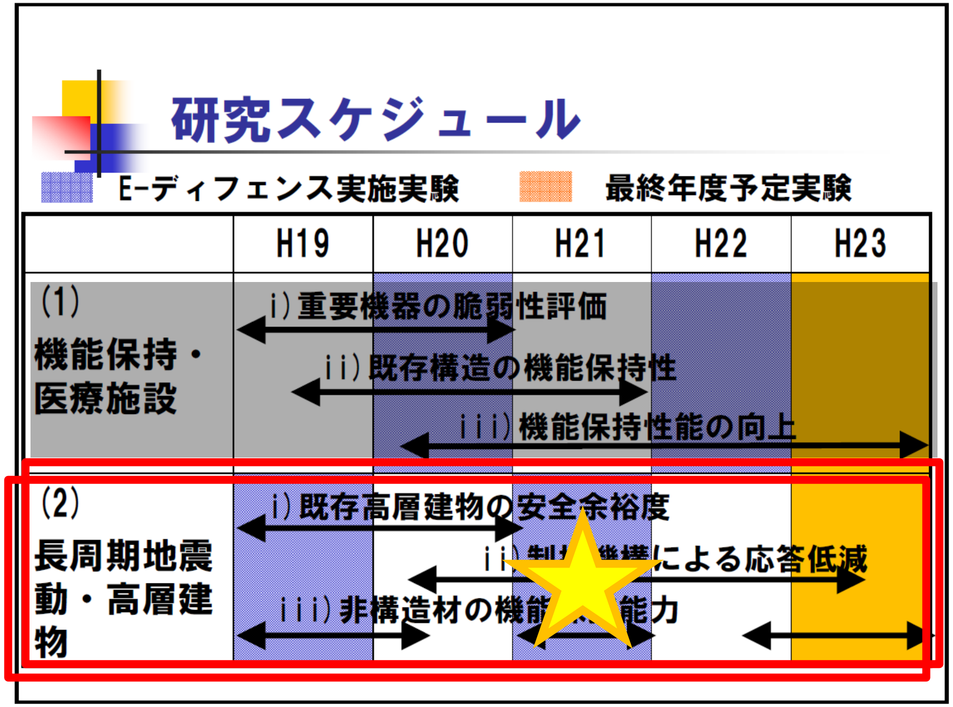
防災科研も今年9月、超高層モデルで制震装置の有効性を試す。全体の2割程度の階に制震装置をつけるだけで、建物全体への被害を大幅に抑えられないかを検証する。

防災科研は「有効性が実証されれば、対策費を大幅に減らせる。役立つデータを提供していきたい」という。



人災を防ぐ補強の根拠と目途

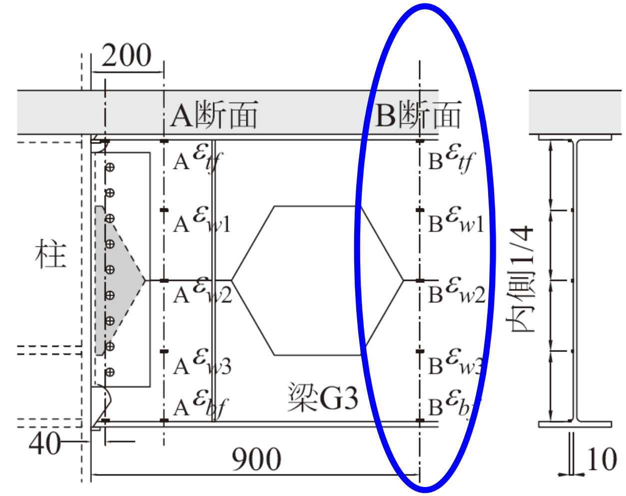
2009

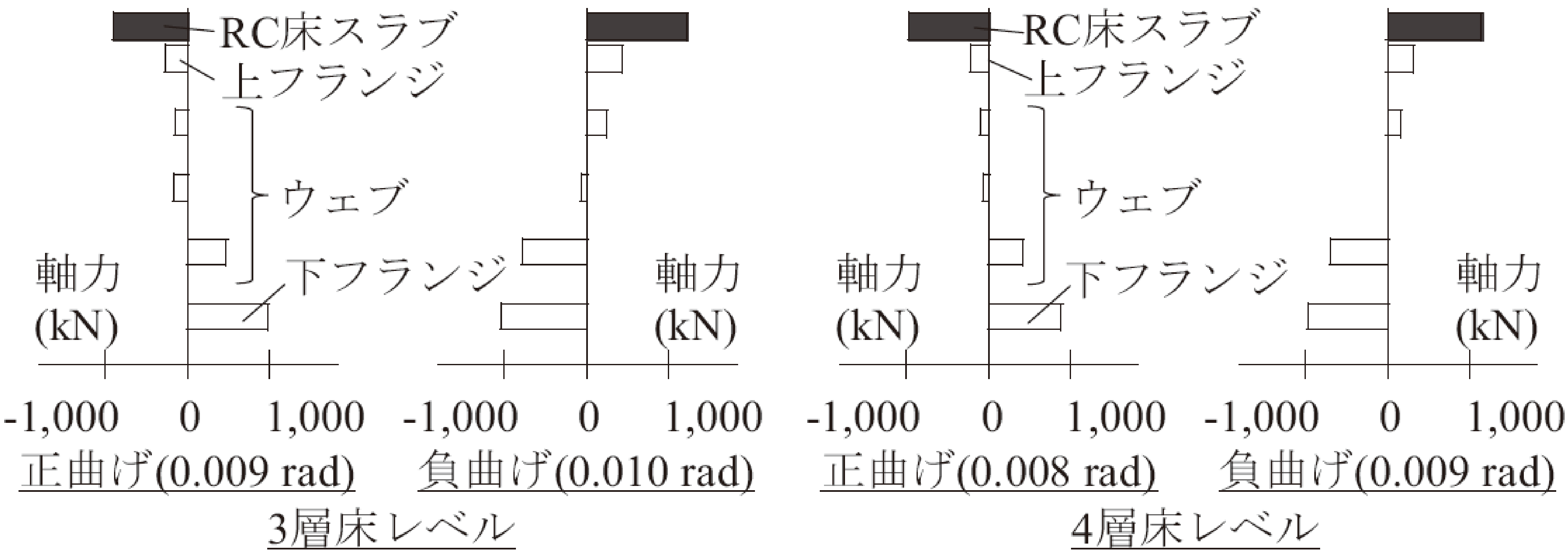


下層を建設，上層部は再利用

RC 床スラブの存在の利用と歪集中緩和

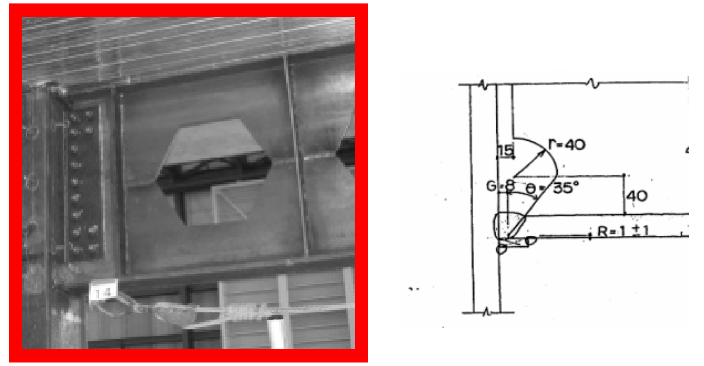
下フランジと同等の応力を負担

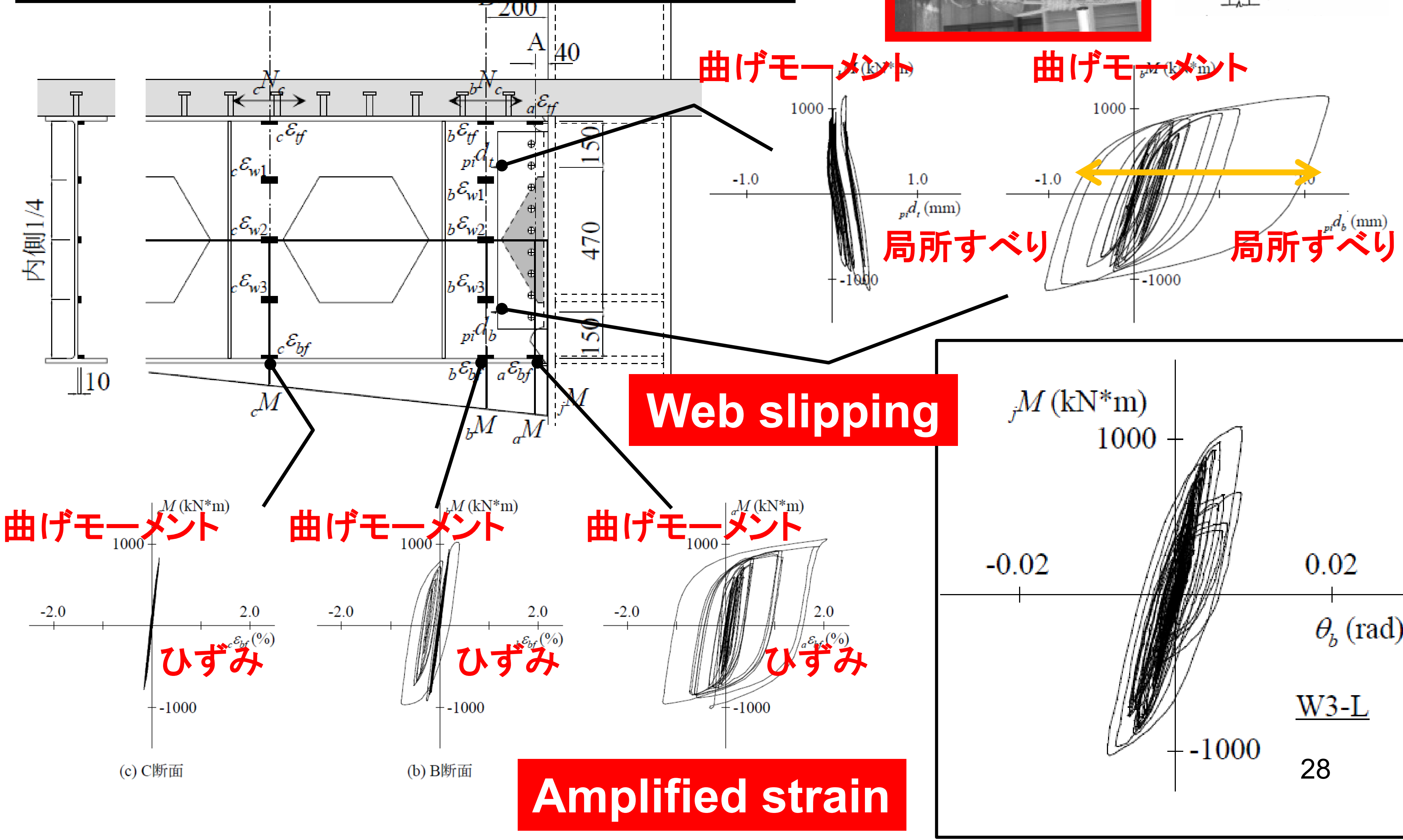




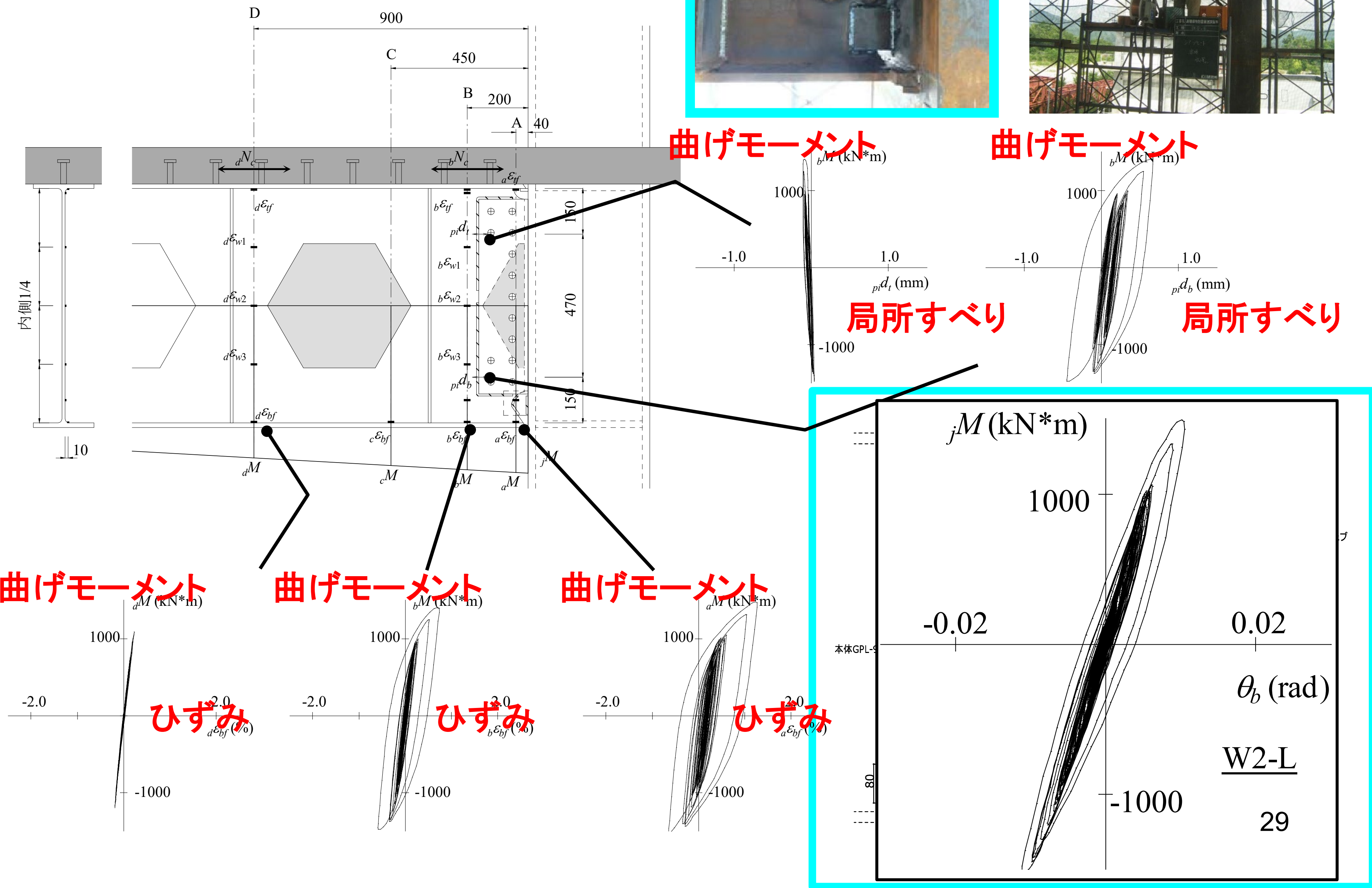
(b) 現場接合部(ハニカム梁)

現場溶接に不可欠なウェブのボルト接合



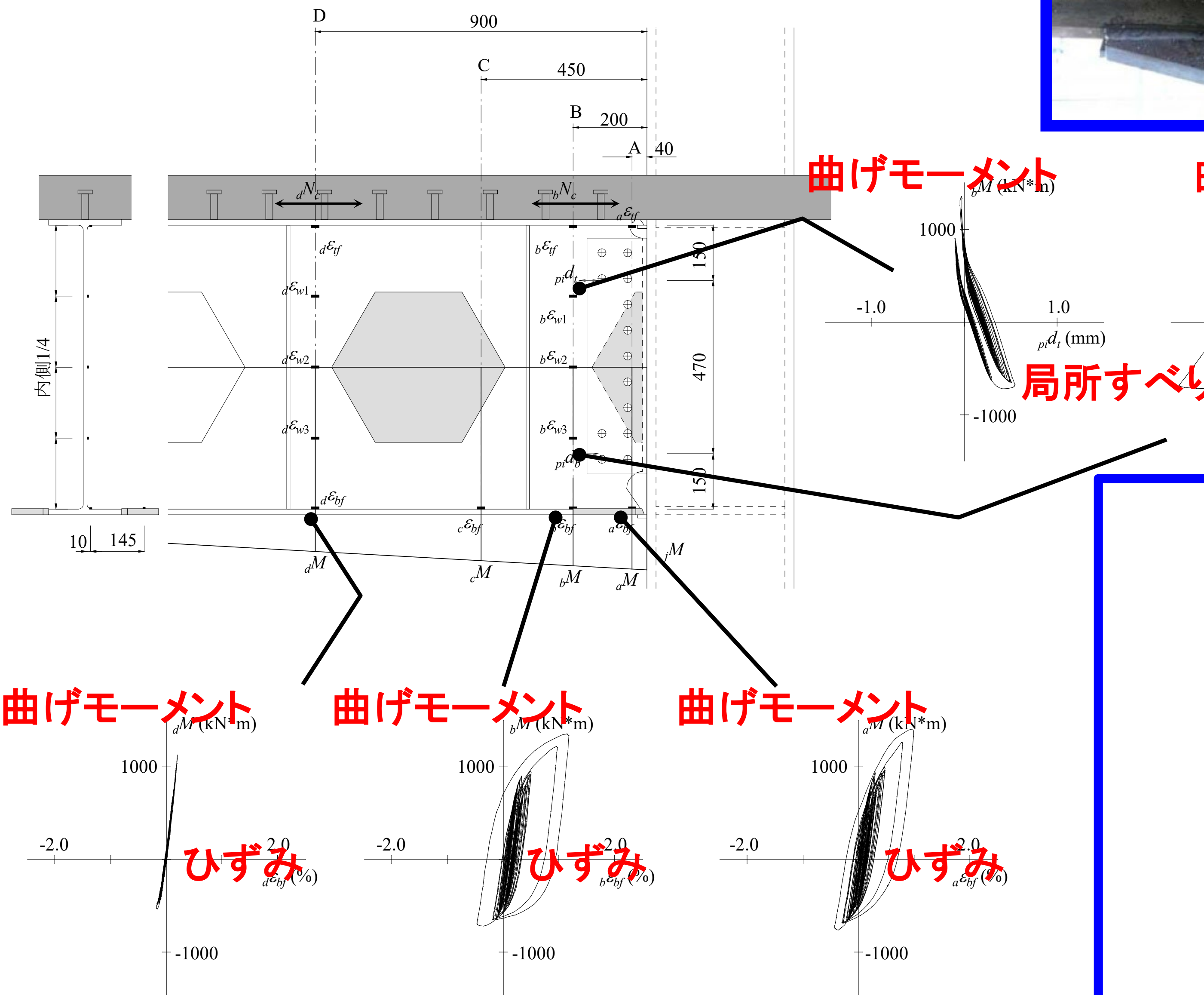


ウェブ溶接補強



D
900
C
450
B
200
A
40
内側1/4
10
160
470
150
曲げモーメント
局所すべり
曲げモーメント
局所すべり
曲げモーメント
ひずみ
曲げモーメント
ひずみ
曲げモーメント
ひずみ
$_jM$ (kN*m)
1000
-0.02
0.02
θ_b (rad)
-1000
W2-L

下フランジ拡幅補強


900
450
200
40
D
C
B
A
内側1/4
10
145
150
470
150
曲げモーメント
曲げモーメント
曲げモーメント
曲げモーメント
曲げモーメント
局所すべり
局所すべり
ひずみ
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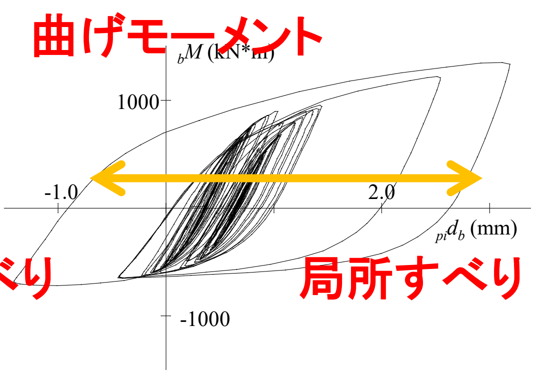
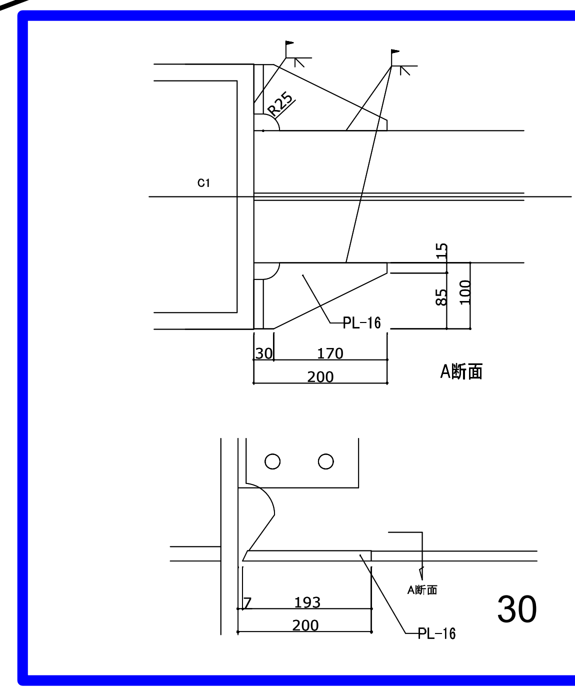
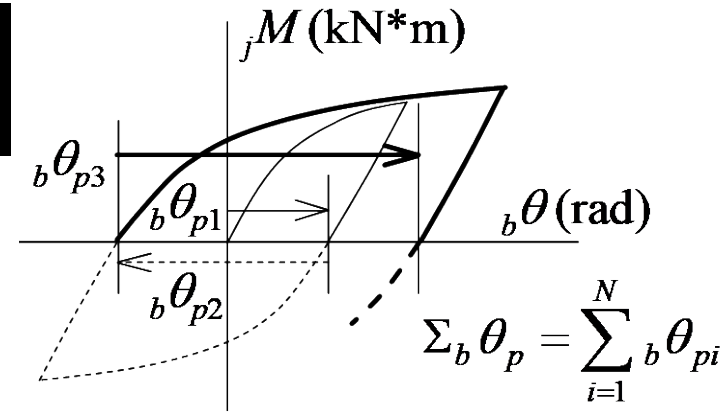
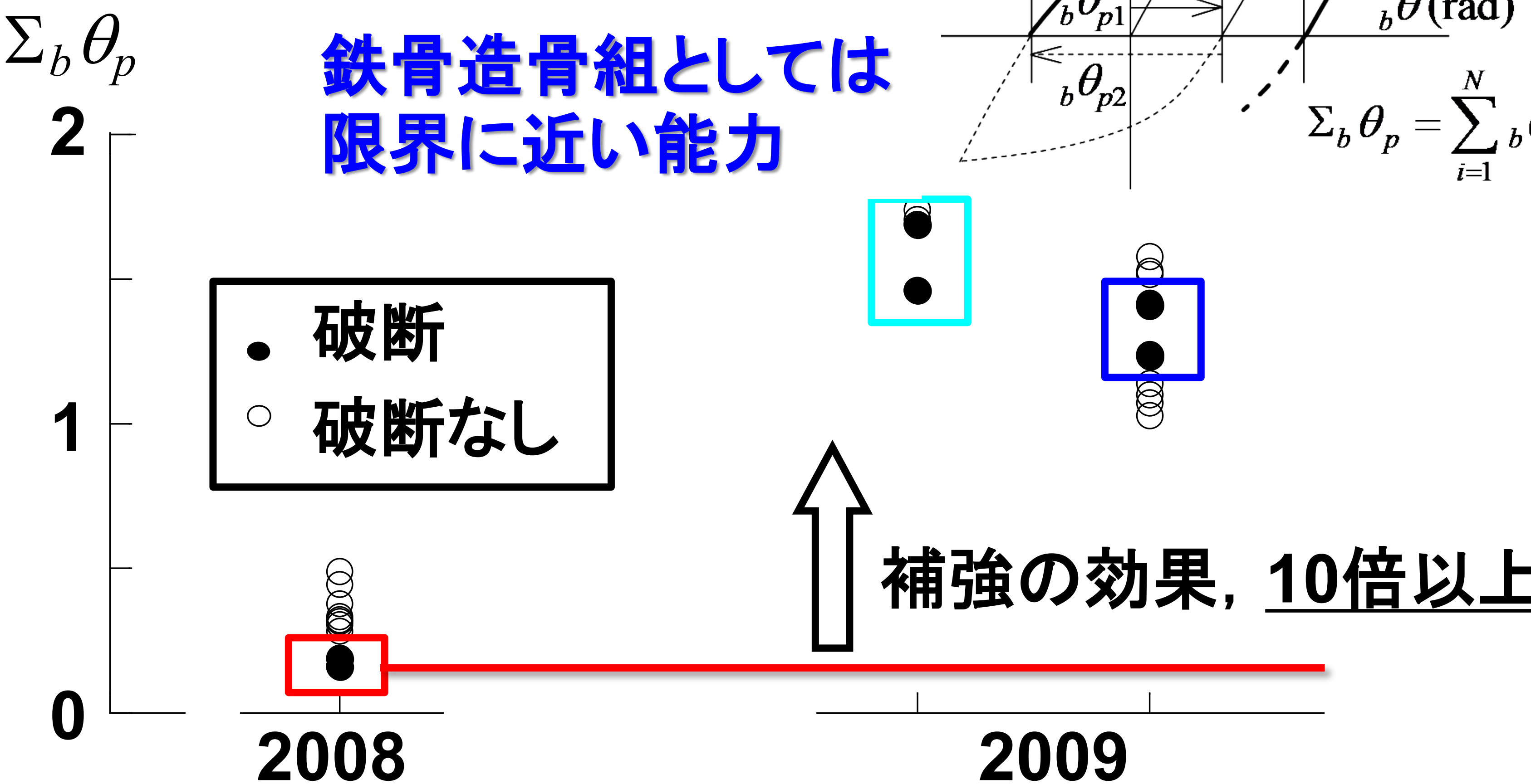
ひずみ
1000
-1000
-1.0
1.0
2.0
-2.0

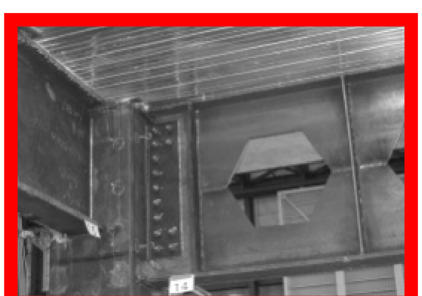



R25
C1
PL-16
15
85
100
30
170
200
A断面
7
193
200
A断面
PL-16

弱点補強の耐震化効率







的を射た補強

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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*

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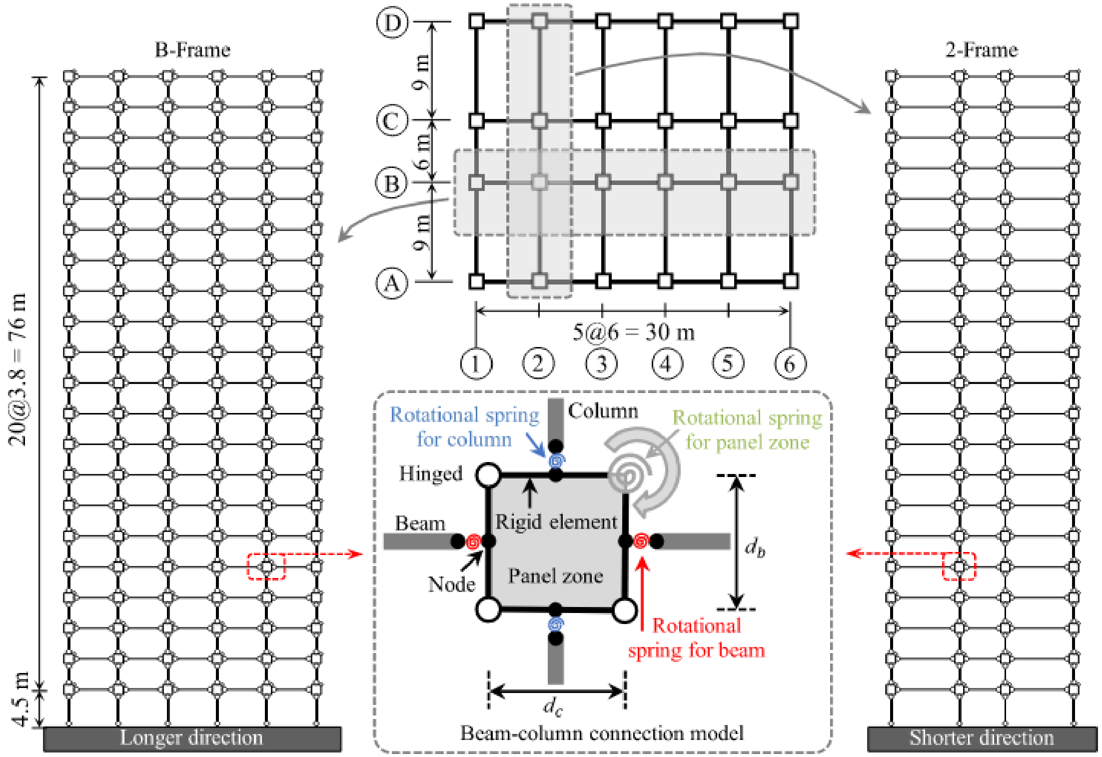
E-Defense shaking table test
Cyclic pushover analysis
Long-period ground motion
Beam-column connection
Fatigue fracture

ABSTRACT

This work presented the experimental and numerical evaluation of the seismic and collapse behavior of Japanese existing high-rise steel buildings subjected to long-period ground motions (LPGMs). Initially, the experiment (E-Defense, 2008) was performed by the full-scale shaking table tests on a typical 21-story steel frame substructure. Accordingly, a nonlinear rotational spring model was used in the numerical modeling. In consideration of the stiffness/strength deterioration and fatigue fracture of beam-column connections, the cyclic pushover analysis was utilized to account for such effect using seismic response data from system-level testing. Subsequently, the numerical model parameters were derived and validated with the initial experiment on the high-rise steel frame substructure. Herein, a well agreement on the seismic failure behavior between simulation and experiment was found in this situation. Furthermore, both field-welded and shop-welded connections on the seismic performance were included for comparison. For the 21-story prototype steel building (built before 1970s), a series of numerical collapse analyses were performed. The above revised model using nonlinear static pushover analysis and time history analysis were conducted to simulate and compare the effects of connection details and composite slabs on the 21-story prototype building. Finally, a cyclic loading protocol for simulating LPGMs was proposed, and the related ultimate failure behavior of the high-rise building was analytically discussed. Critically, this work



Mass distribution

Floor	W_i (t)	W_i (kN)
RF	711.5	6973.0
21F	586.6	5749.0
20F	586.6	5749.0
19F	589.5	5777.0
18F	593.9	5820.0
17F	595.1	5832.0
16F	598.4	5864.0
15F	603.6	5915.0
14F	604.9	5928.0
13F	610.6	5984.0
12F	616.7	6044.0
11F	619.1	6067.0
10F	624.1	6116.0
9F	629.2	6166.0
8F	629.8	6172.0
7F	630.8	6182.0
6F	631.6	6190.0
5F	632.0	6194.0
4F	632.0	6194.0
3F	632.4	6198.0
2F	643.3	6304.0
Sum	13001.8	127418.0

	Beam	Column	Panel zone
Material	Modified IMK (Bilin) + Fatigue material	Modified IMK (Bilin) material	Elastic material
Element	Elastic Beam-Column + Zero-Length		

Fig. 17. Numerical model of 21-story steel moment resisting frame (prototype building).

日本建築学会　研究委員会
大地震時耐震性能評価小委員会（修復コスト･確率論的評価）
地震動WG，S造WG，RC造WG，木造WG，二次部材WG

大地震時耐震性能評価小委員会　2021年4月 ～ 2025年3月

設置目的

日本では，1995年兵庫県南部地震以降，最近では2016年熊本地震に至るまで，繰り返し被害地震が発生し，その度に基準法の定める極稀の地震動を大きく上回る地震動が観測されてきた。今後も，関西・中京圏では南海トラフ地震の，首都圏では中短期的にはM7級の，長期的にはM8級の相模トラフ地震の発生が懸念されている。

本小委員会では，これらの地震に対する地震動を評価するとともに，近年の振動台実験を参照して大振幅の予測地震動に対する応答評価の確からしさを確認するとともに必要な改善提案を行う。また，損傷の評価を行うためには損傷発生の限界値が必要であることから，これまでに蓄積されてきた部材実験の成果を集約して，部材損傷の限界値の評価を行う。併せて，損傷によるコストと事前対策に要するコストについても試行的な検討を行う

⬇ **現状を踏まえた効果的な研究計画（2023年度，2024年度）を策**
構想の具体化，修正，補強

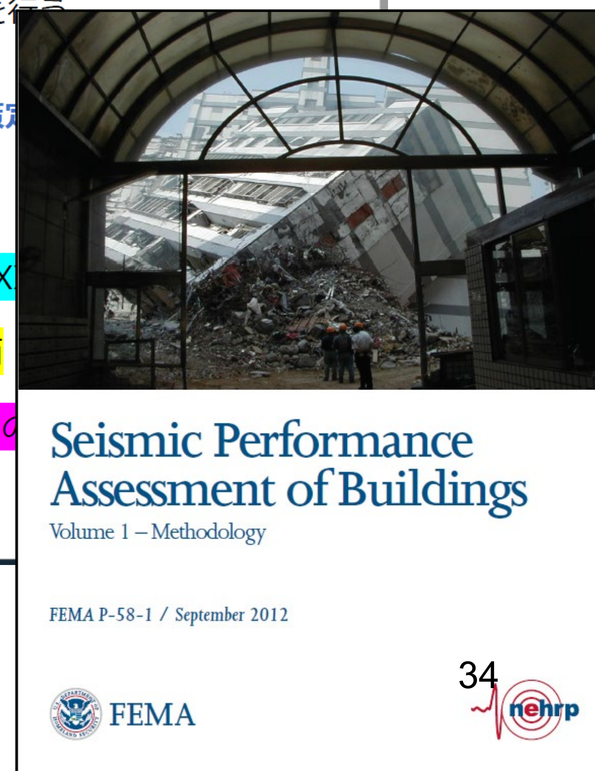
(1) 首都圏相模トラフ地震，関西・中京圏での南海トラフ地震における最新の地震動評価，X

(2) 詳細解析を利用する応答評価法の検討，(3) 地震ハザードIMと応答値EDPの相関性評価

(4) これまでに蓄積されている部材実験に基づき，部材損傷の限界値の評価，フラジリティの

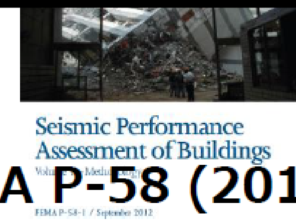
(5) 損傷によるコストと事前対策に要するコストを評価し対比

Response Assessment Enhancement, Utilizing Shaking Table Test Data

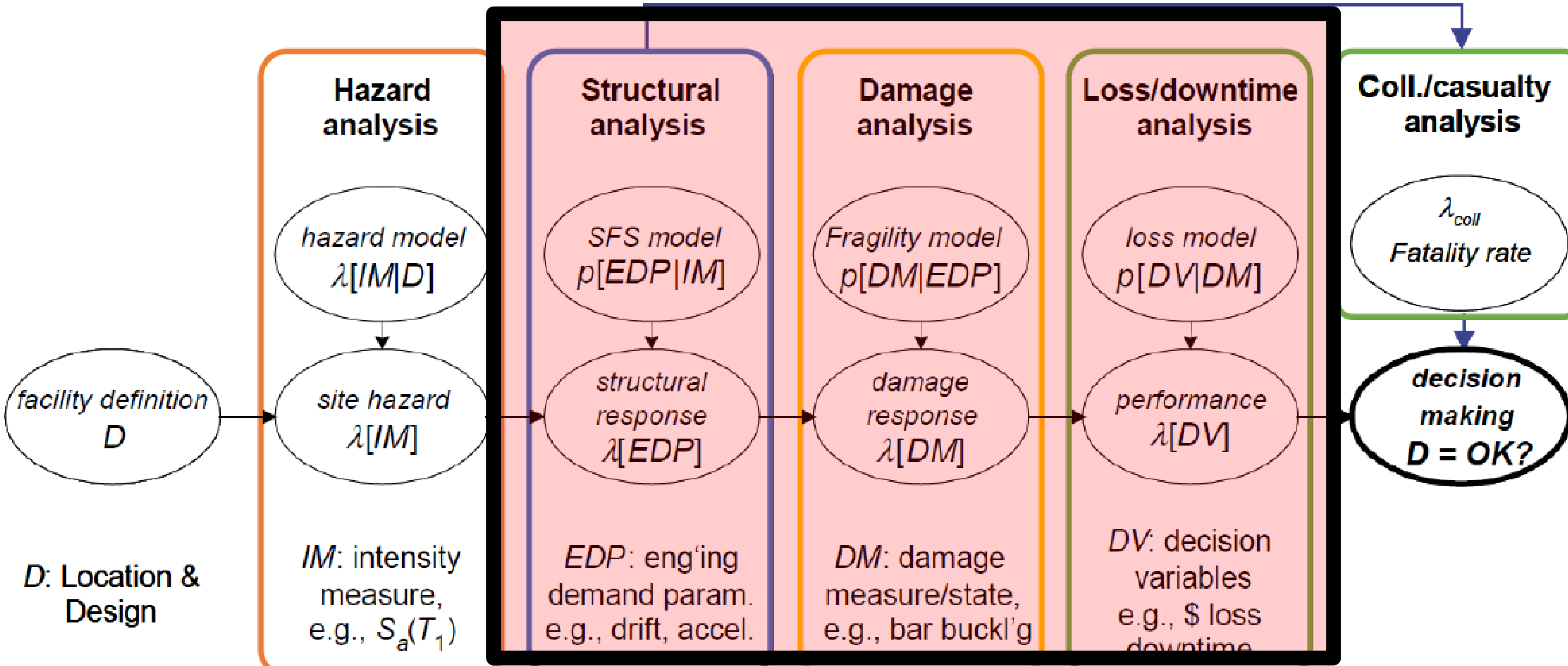


地震応答のばらつき，各部材損傷の不確定性，修復方法・コスト関数の不確定性を対数正規分布で評価

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



FEMA P-58 (2012)



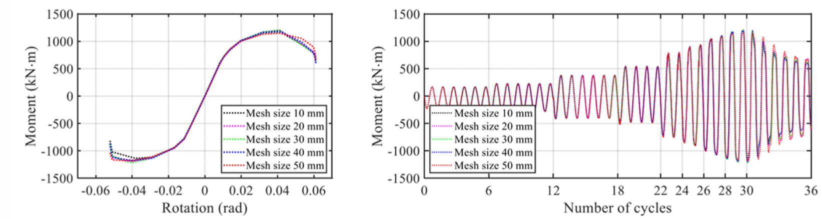
地震動は相模トラフ地震を想定したシナリオ地震動群
⇒相模トラフ地震が起きることを前提
⇒各建物の修復コスト比較による免震，制振等の高耐震化推進

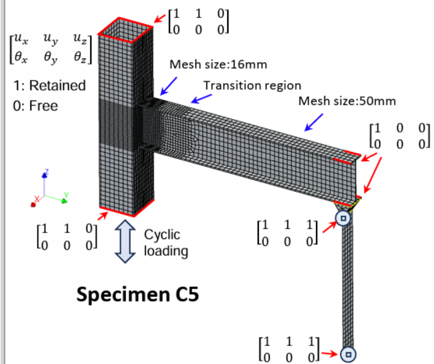
3D FEM analysis on steel frame structure

Nagoya university
Nagae LAB.
PH.D student
Tianhao Yan

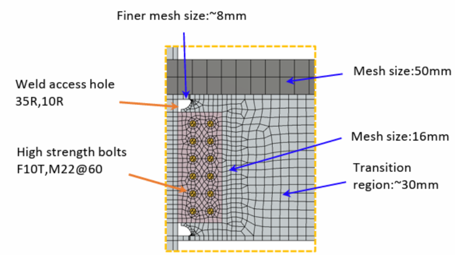
FE modeling

Mesh sensitivity analysis



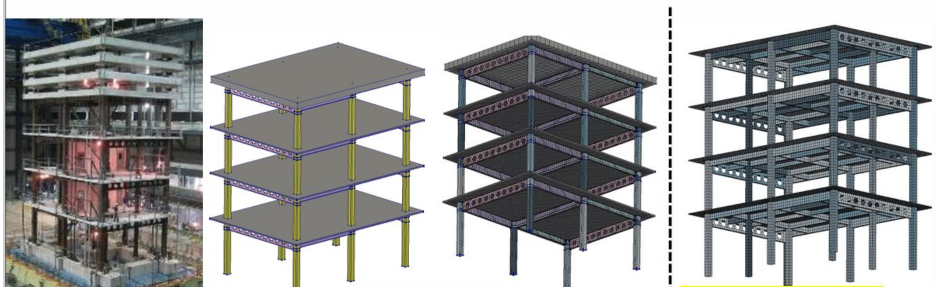


Specimen C5

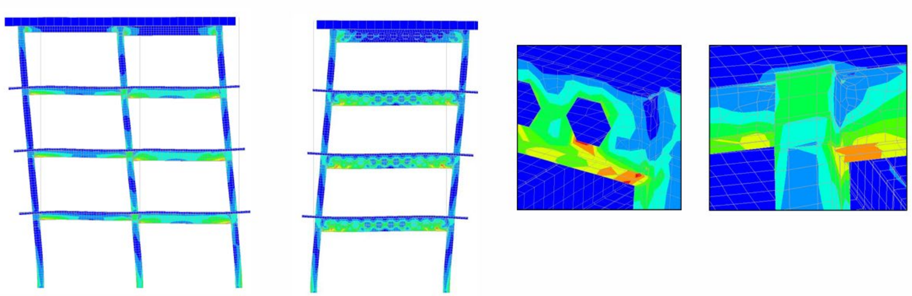


Specimen C3

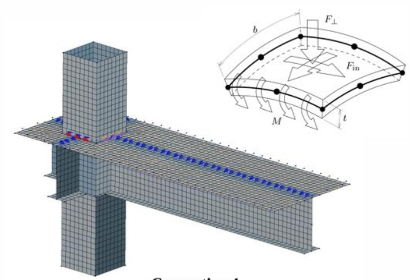
Future work (2008 high-rise frame structure E-Defense test)



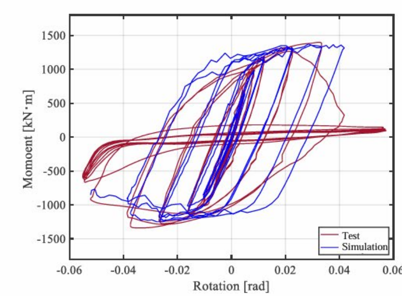
Solid element **Curved shell element**

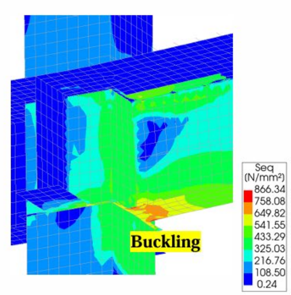


FE modeling using curved shell element

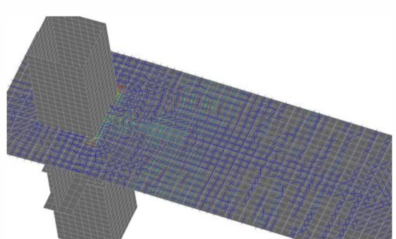


Connection 4



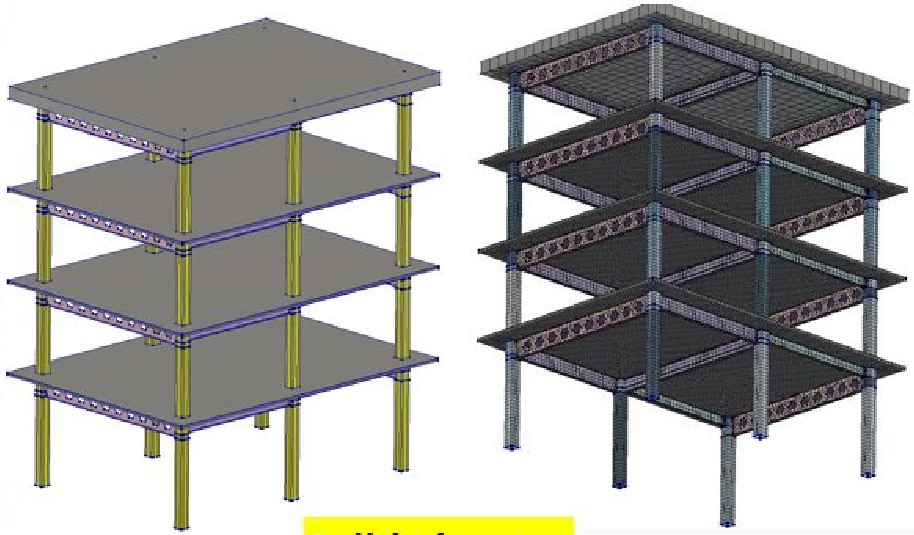


Buckling



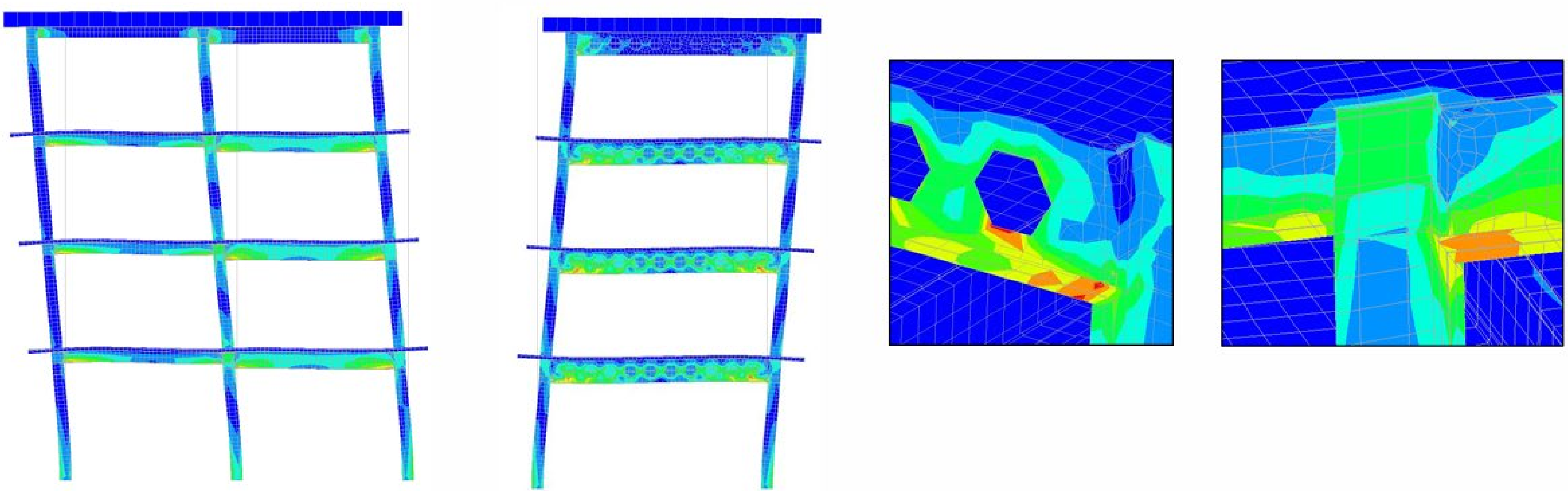
Crack distribution

Future work (2008 high-rise frame structure E-Defense test)



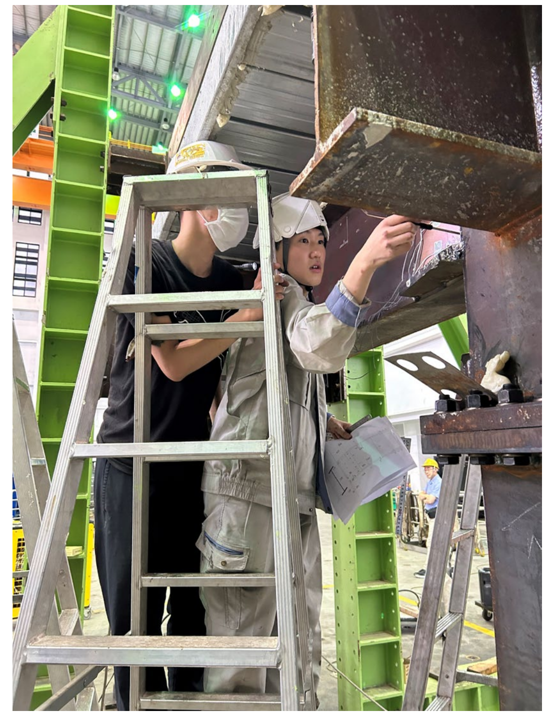
Solid element

Curved shell element



破断後補修実験（台湾國立成功大学）

August, 2023
Shigeta from Nagoya University



April-September, 2024
Students of Nagoya University

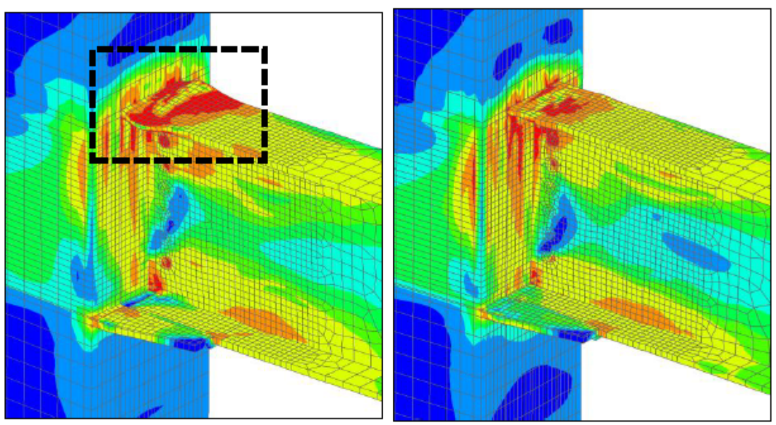
破断後補修FEM解析

Nagoya university
Nagae LAB.
PH.D student
Tianhao Yan

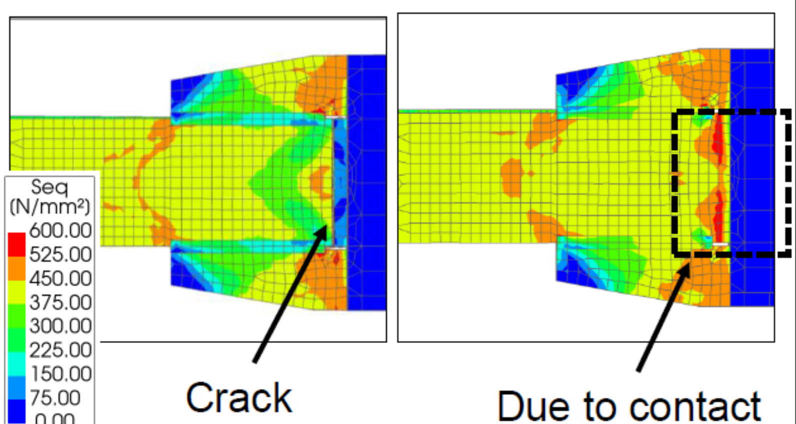
FE result (von-Mise stress distribution)

2022 repaired A

+0.04 rad **-0.04 rad**

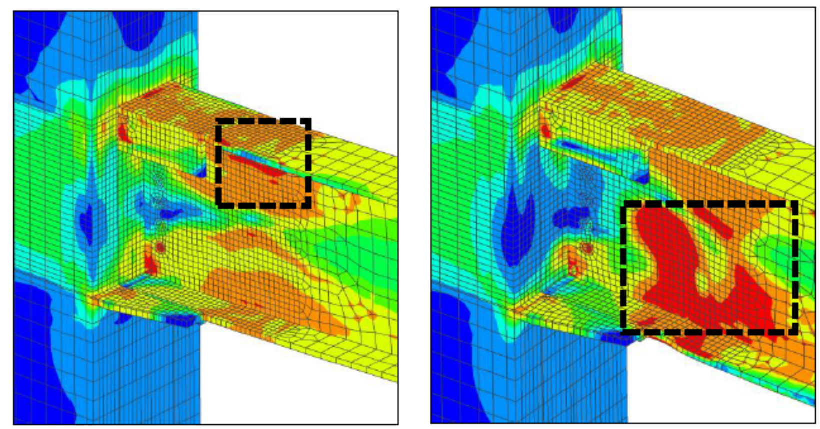


Concentrated at the end of the top flange

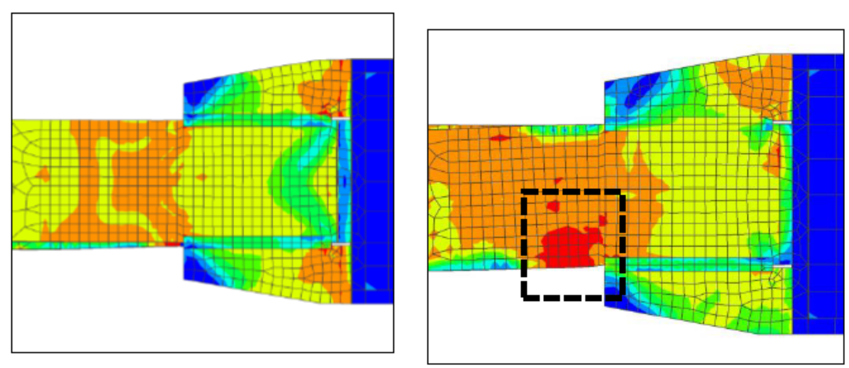


2022 repaired B

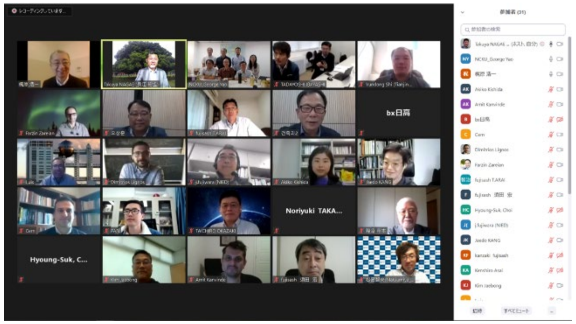
+0.04 rad **-0.04 rad**



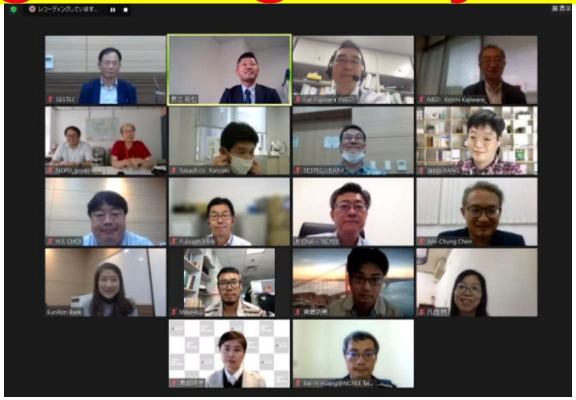
Concentrated at the web away from the beam end



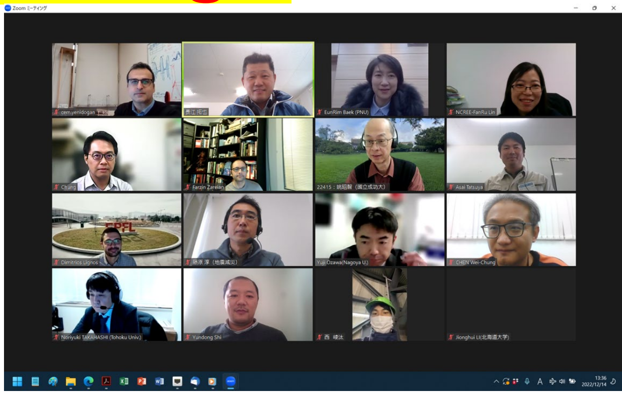
8 country meeting arranged by the Triangle



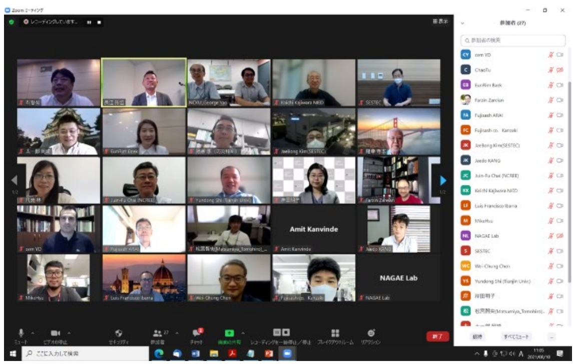
The 2020 November



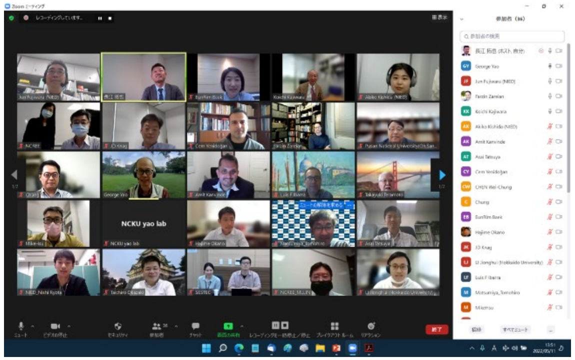
The 2021 May



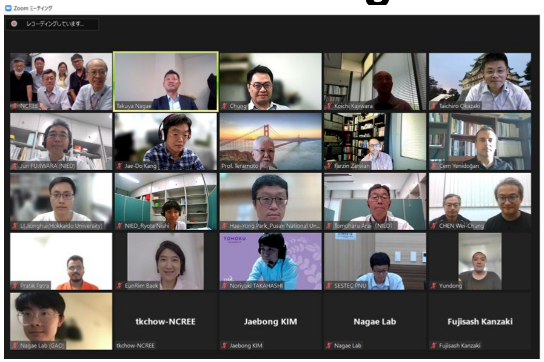
The 2022 December



The 2021 August



The 2022 May



The 2022 August

The 2022 November

条件の良い鋼構造骨組のシミュレーション⇒高い確度

3-D DETAILED FINITE ELEMENT ANALYSIS OF FULL-SCALE SHAKING TABLE TEST ON A 10-STORY STEEL BUILDING

J. Fujiwara[1], T. Nagae[2], T. Yan[2], J. Jin[2], J. Li[3], T. Okazaki[3], A. Kishida[1], R. Nishi[1] & K. Kajiwara[1]

[1] National Research Institute for Earth Science and Disaster Resilience, Miki, JAPAN,

j.fujiwara@bosai.go.jp

[2] Nagoya University, Nagoya, JAPAN

[3] Hokkaido University, Sapporo, JAPAN

Abstract: *In February 2023, a three-dimensional dynamic loading test was conducted on a full-scale 10-story steel frame structure at E-Defense, NIED, Japan. This test aimed to gather data for the advancement of seismic structural technology and serve as an exceptional case study for the development of new numerical modeling methods. This research proposes a 3-D full-scale finite element modeling approach, taking into account the nonlinear characteristics of steel and concrete floor slabs. In this finite element model, columns, beams, panel zones, and concrete floor slabs were all modeled using curved shell elements. A comparison was conducted between the numerical simulation and the experimental results regarding their dynamic characteristics and seismic response in the transverse direction (moment resisting system). Subsequently, the local responses of components such as the panel zone shear rotations, stress distribution in beam-column connections, and the development of floor slab cracks under JMA Kobe 100% excitation were compared and discussed. The findings indicated that the 3-D curved shell model replicates reasonable simulation of the overall behavior, and offered reasonable predictions of the plastic behavior of local components.*

Keywords: *E-Defense shaking table test, 3-D full-scale finite element modeling, Nonlinear response history analysis*

1. Introduction

In performance-based seismic design frameworks (FEMA-355E, 2000), the commonly adopted approach involves conducting a series of nonlinear time-history analyses using plastic hinge models to predict the response of buildings at various seismic intensity levels. Subsequently, the predicted seismic response is compared to acceptance criteria defined based on target performance levels. However, some past experimental studies (Nakashima et al. 2007, Matsumiya et al. 2010) have indicated that the actual seismic response of structures, such as the effect on the stiffness and strength of the concrete floor slab to beam members and floors, is greater than anticipated in design practice. Therefore, in performance-based seismic design methods, it is vital to establish a sensible and authentic numerical model for the precise evaluation of building performance and earthquake-induced damage.

In recent years, with the advancement of finite element software, creating 3D finite element models capable of simulating various strong nonlinear effects has become increasingly straightforward. However, the application of refined finite element modeling has primarily been centered around individual structural components (such as beam-column connections), with only a minority of researchers conducting detailed finite

3. Modeling methodology

Based on the experiment dimensions and material properties mentioned above, a 3-D full-scale curved shell finite element model was constructed using the finite element analysis software DIANA10.6 as shown in Figure 3. This section will provide a detailed explanation of the methods and conditions used in setting up the numerical model.

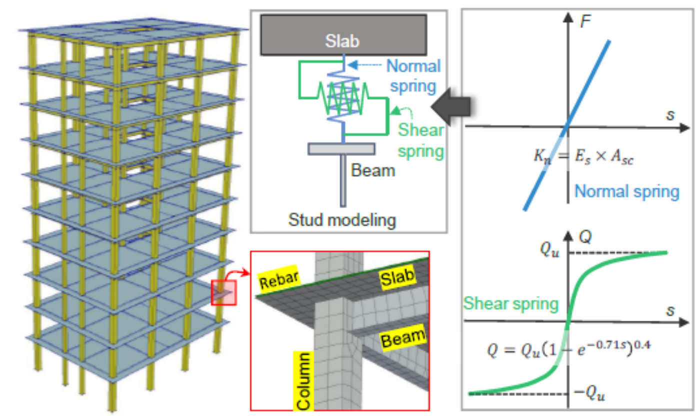


Figure 3. Finite element model.

numerical model effectively captures specific phenomena observed in the experiments, notably the significant shear deformation of the 2C panel zone. Future work will focus on evaluating the seismic response of the longitudinal direction including BRBs and the biaxial effects of the test specimen.

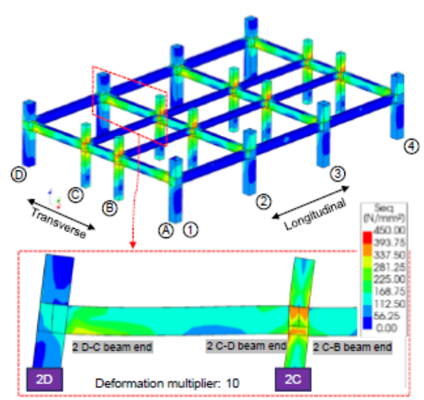


Figure 10. Von-Mise stress distribution of the 4th floor (maximum response under JMA Kobe 100%).

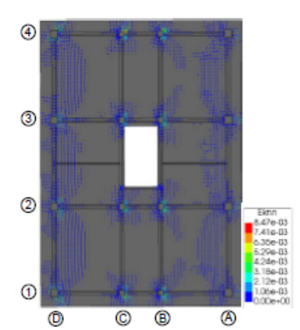


Figure 11. Crack of the 4th floor slab (under JMA Kobe 100%).

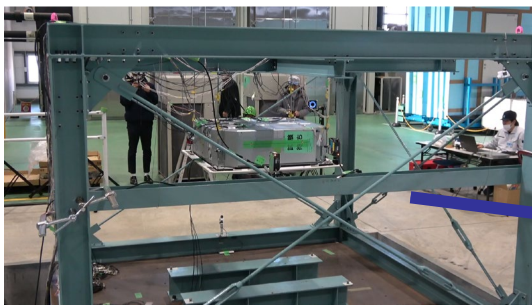
Recent high-rise steel building test

Continued Testing in Aug. 2024（M2 重田永生, 成功大学留学）

Test Objective

- Pendulum base-isolation testing to verify the impacts towards NSCs
- Check the effect of vertical motion on non-structural components
- Check Pendulum base-isolator behavior for loss assessment

Test1: with Pendulum base-isolator
Test2: without Pendulum base-isolator

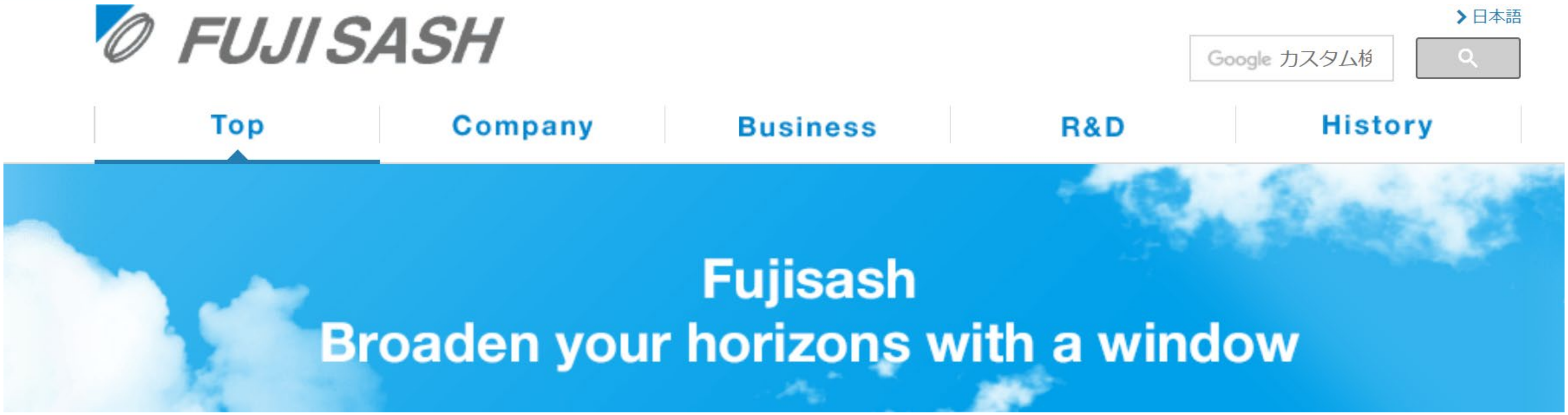


2021 NCREE

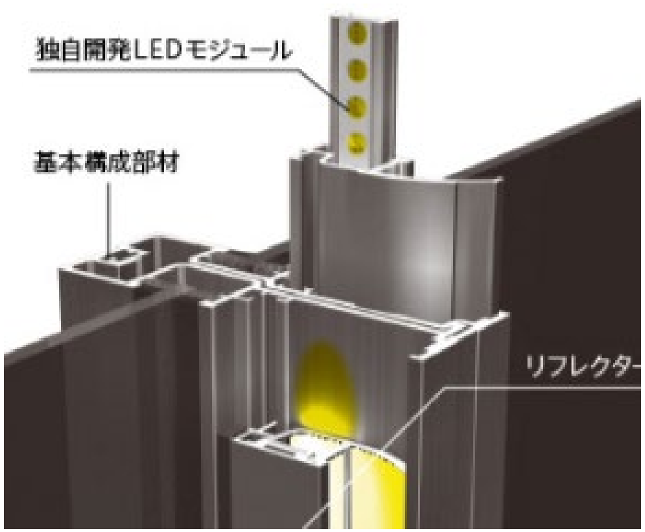
Pendulum base-isolator (NIPPON STEEL)

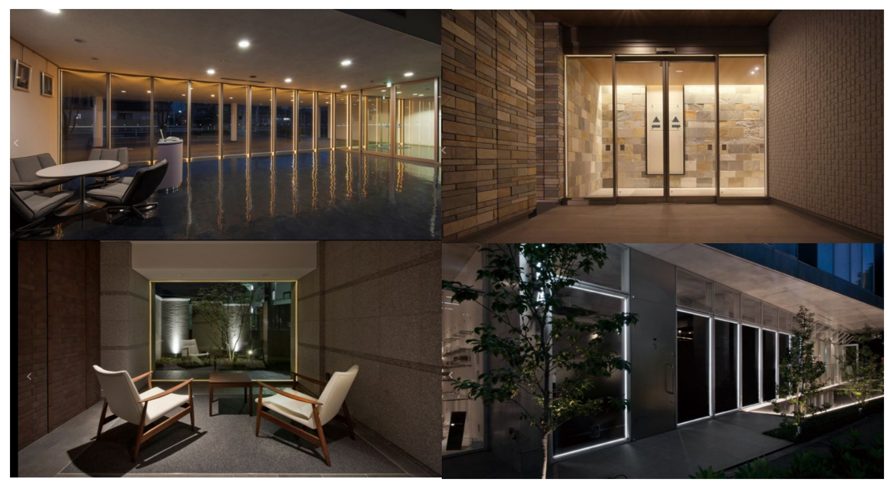
Equipment on 9th Floor at E-defense test (DAIKIN)

From senior Takaya



→ アンビエントライトによる建築演出の技術が先行して開発されており製品化





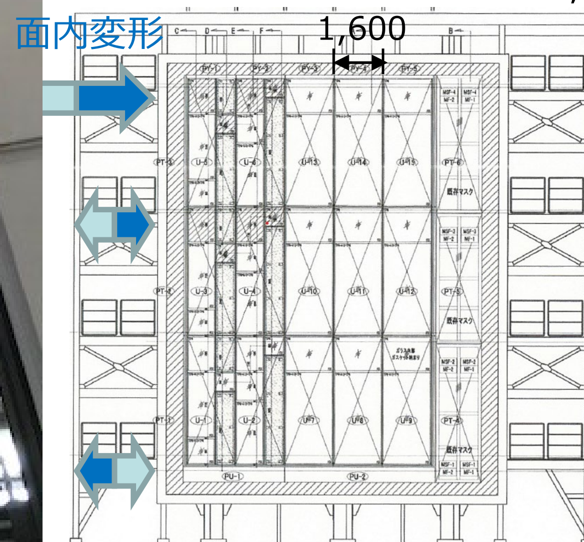
→ 層間変形計測技術と表示技術への展開

高層用ユニットカーテンウォール検証時

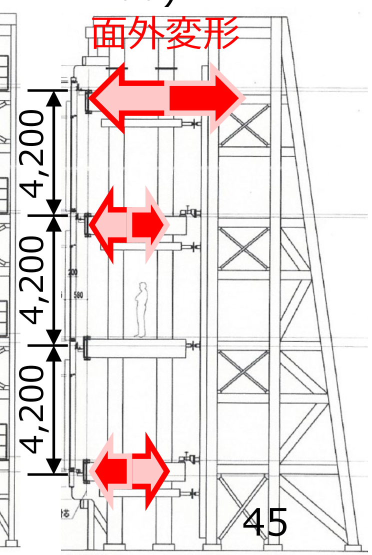
面内変形
層間変形角(1/100 rad)

面外変形
層間変形角(1/100 rad)

各ユニット高さ:4,200mm



試験体立面図



試験体断面図

科研費・挑戦的研究（開拓）

2006

応急危険度判定の問題に対する各段の改善へ

Wo

H

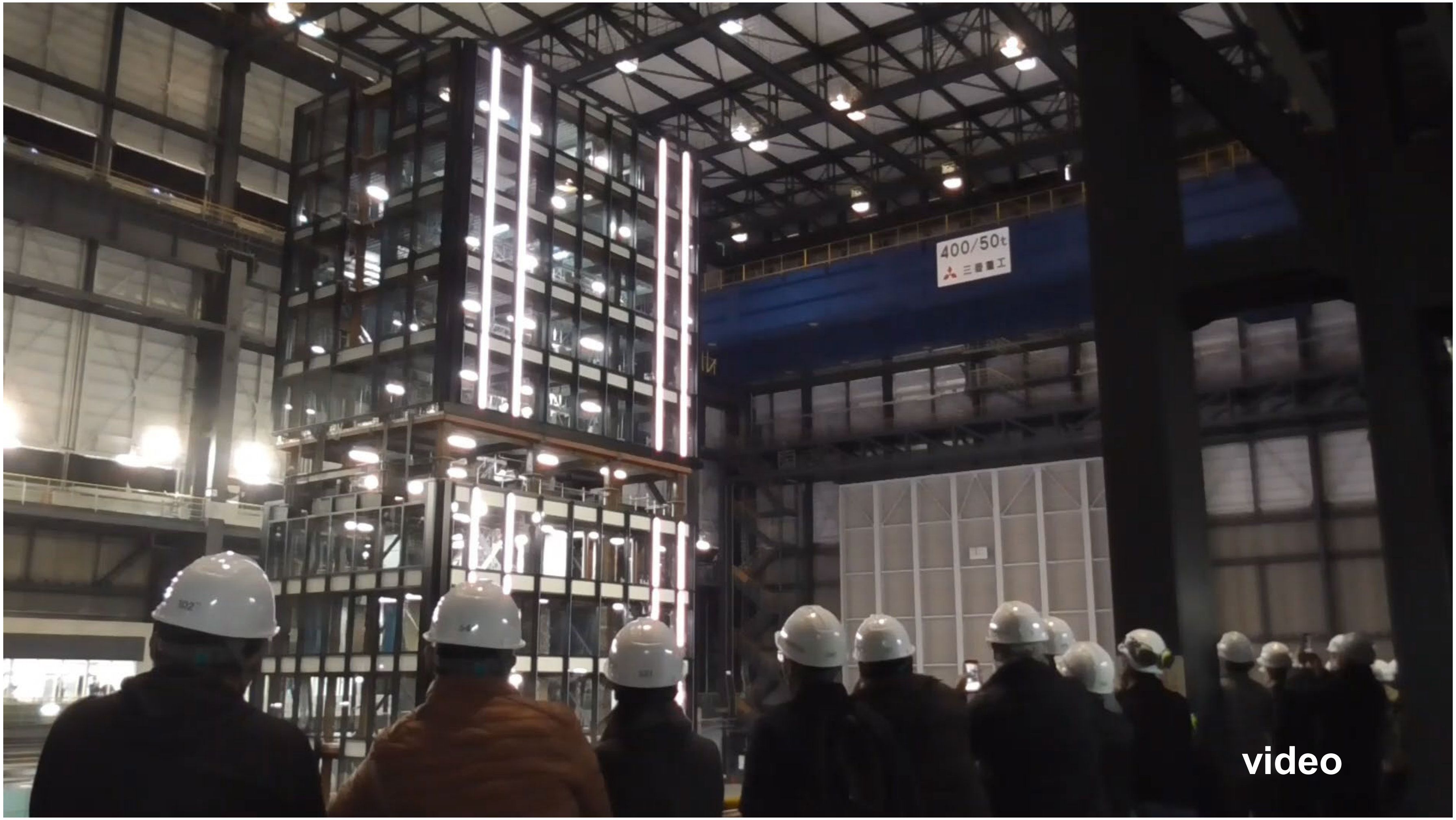
Lo :

S ities

0.01 rad → Yellow
0.02 rad → Orange
0.03 rad → Red

2023.2 大規模な動的検証によるエビデンス

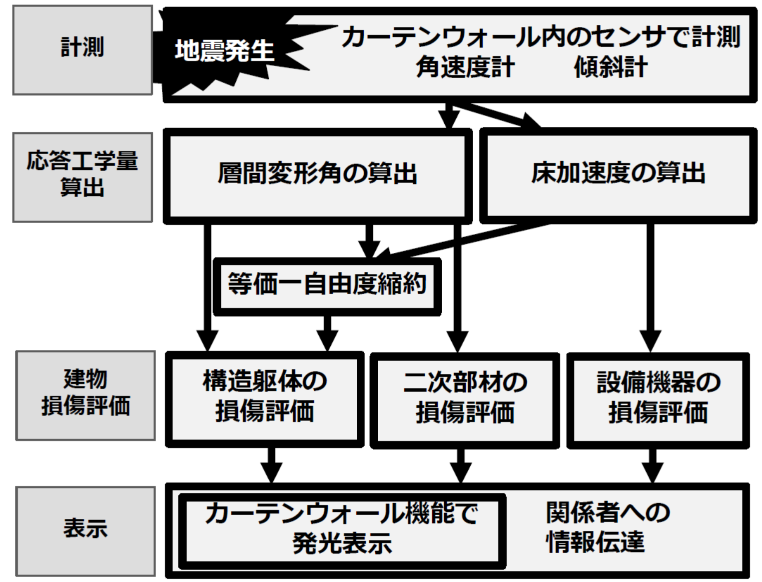
Damage assessment, displayed by LED



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　崚太　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

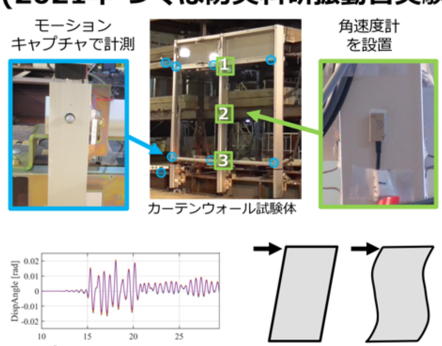
カーテンウォール内蔵型センサ・アラートシステム



これまでの取り組み

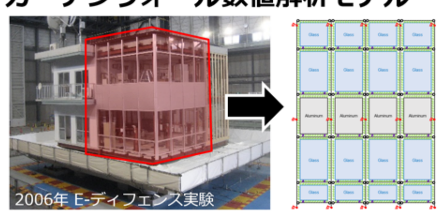
①カーテンウォール 地震時性能評価

カーテンウォール振動台実験分析 (2021年 つくば防災科研振動台実験)

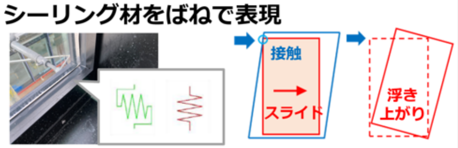


構造躯体への追従性能　**サッシの複雑な変形**

カーテンウォール数値解析モデル



シーリング材をばねで表現



ガラスの浮き上がり・スライドを表現

2022年日本建築学会大会学術講演会で発表

角速度→層間変形角　**算出方法**

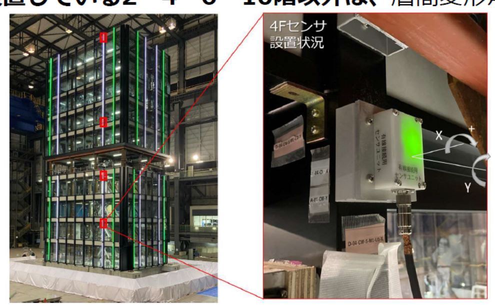
層間変形角の算出

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。**

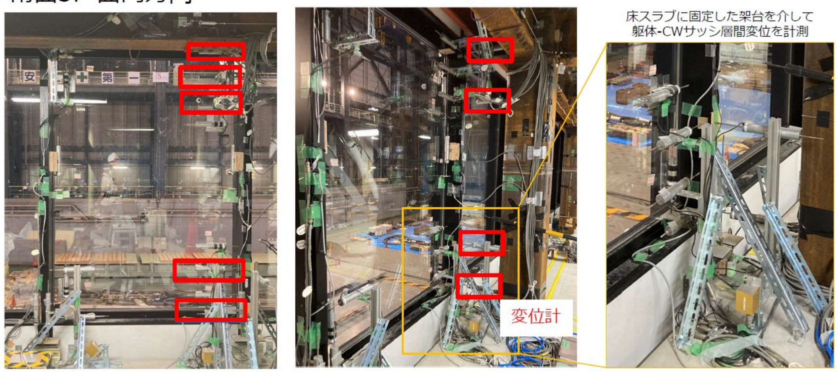


センサ設置状況

①カーテンウォールサッシの変形について 9

- センサ・アラートシステムではカーテンウォールサッシ縦材(方立)の**局所回転を計測するセンサを用いる。**
  ←サッシの変形形状の把握が必要。
- **躯体変形が最大となった3F**カーテンウォールを集中的に計測。

南面3F-面内方向　南面3F-面外方向

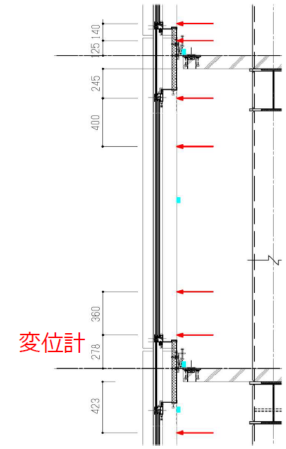


3F ノックダウン方式カーテンウォール接触型変位計設置状況

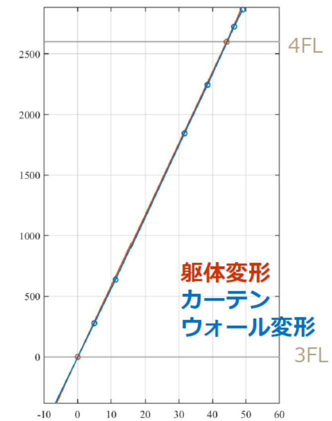
カーテンウォール方立(サッシ縦材)の変形形状　面外方向 11

サッシ縦材のどの場所でも躯体変形と同様の変形角を示す。

→ (現段階では)
面外方向の計測がセンサ・アラートシステムに採用されている。



3F 面外方向計測状況

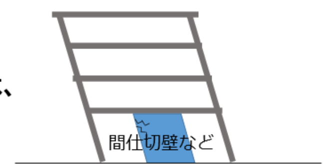


3F 面外方向カーテンウォール
最大変形図(層間変形最大時)

②角速度を用いた層間変形評価 13

目的：二次部材の被害評価

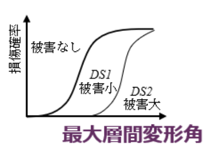
層間変形に追従する間仕切壁などの二次部材は、最大層間変形に応じて被害が発生する。



(a) 開口部全体の残留変形　(b) 開口部上部ボード脱落　(c) 下端部のつぶれ進行

2020年つくば防災科学技術研究所ユニットハウス非構造実験[2]

実験データの蓄積に基づき整備されるフラジリティ曲線を用いて評価するために、角速度から層間変形角を算出する。



2)後藤航，小林俊夫，石原直，梅田尚子，岡野創，八百山太郎，浅井竜也，長江拓也，貞本美和，小林祐亮，林徹，神崎喜和，梶原浩一，岸田明子，藤原淳:2次部材の耐震性能に関する実験研究の進展と評価技術の現状, 2021年度日本建築学会シンポジウム「大振幅地震動に対する耐震性能評価」 2021.12

加速度算出方法 22

①相対加速度の算出

角速度 → **計測ノイズ除去** (0-30Hzバンドパスフィルタ) → **微分** → **角加速度** → **×層高さ** → **相対加速度**

本実験では、2,4,6,10階に角速度計を設置。
角速度計設置のない層は、上下層の角加速度を線形補完。

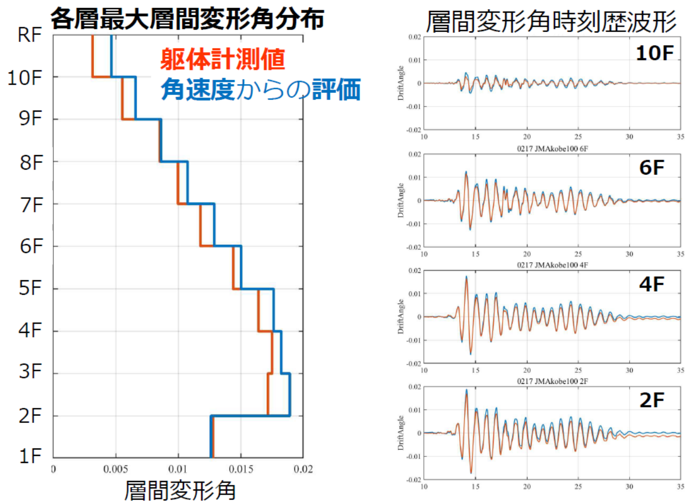
②絶対加速度の算出

nF床加速度 = RF床加速度 - [10層相対加速度 + 9層相対加速度 + ・・・ + n層相対加速度]

加速度計で計測した屋上階床加速度から、
①で算出した相対加速度を引いていく。

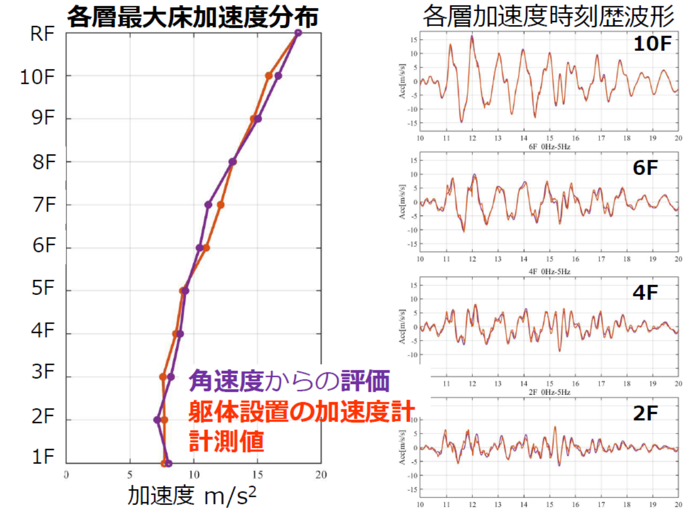
2023.9.15 AIJ conference

層間変形角算出結果　JMA神戸100%加振時



- **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



- **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

目的：建物構造安全性評価

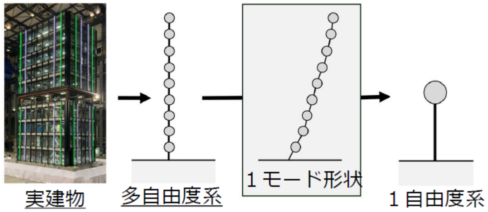
全体崩壊は、梁端の局所的破断の集積で決まる。

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。

E-defense18層鉄骨実験(6)

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。

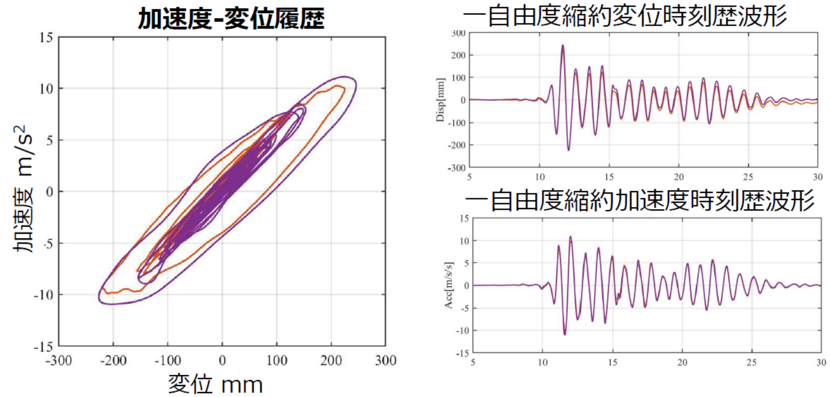


$$S_D(t) = \frac{\sum_{i=1}^{10} m_i\,\beta u_i \cdot \delta_i(t)}{\sum_{i=1}^{10} m_i\,\beta u_i}$$

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

6)久保田淳, 高橋元美, 鈴木芳隆, 澤本佳和, 曽高裕治, 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



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**

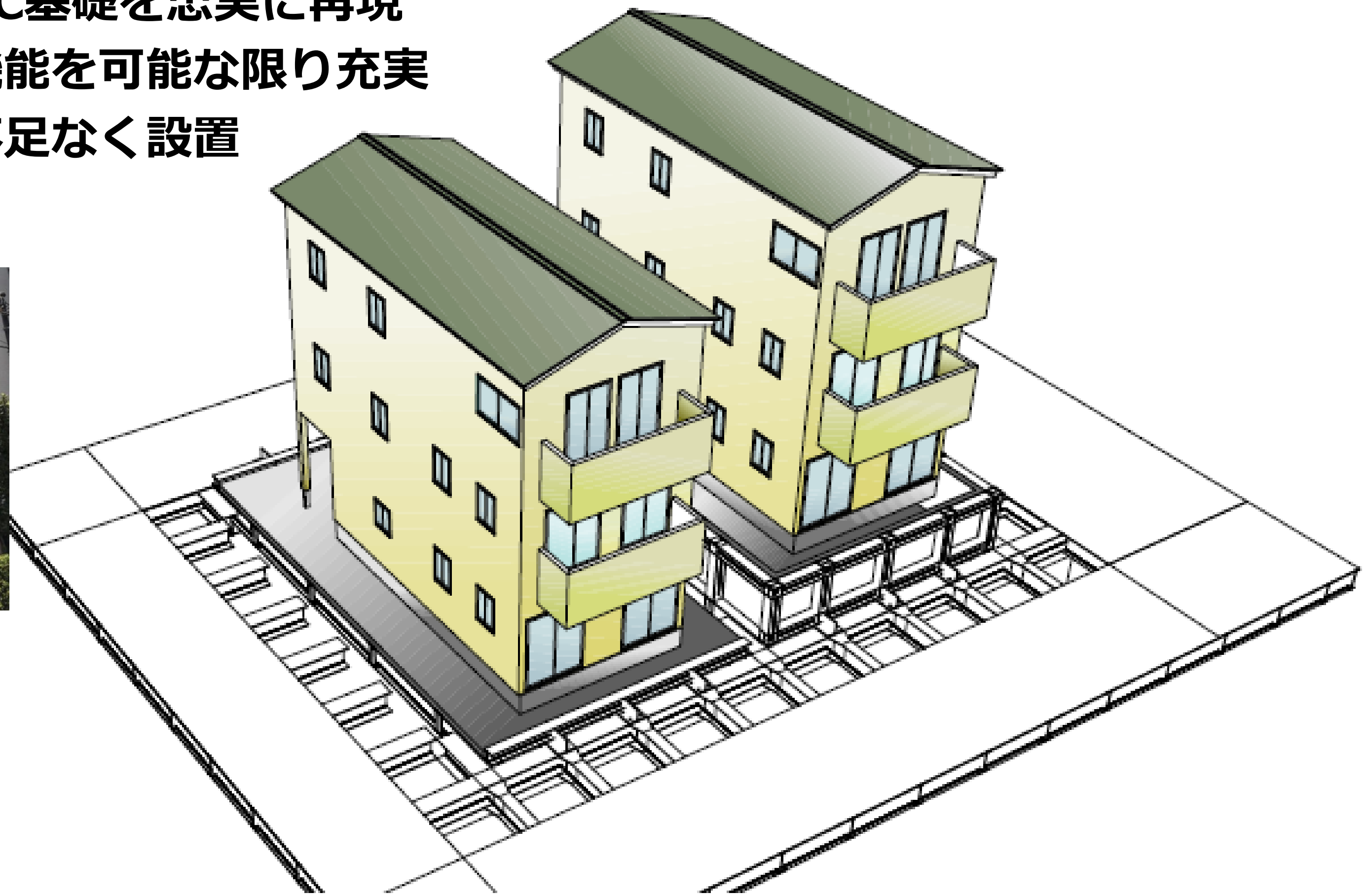
- **1つの加速度計と、4つの角速度計で10層建物の力-変位関係を適切に評価できる。**
- 変位・加速度ともに1.1~1.3倍程度大きく評価される。

Topics

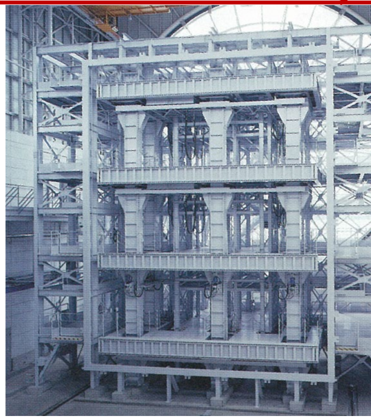
1. High-rise building by substructure testing
2. Sensing technology with the industrial
3. **Soil structure interaction highly inelastic**
4. Detailed simulation with the industrial

2018 E-Defense 実験 ⇒ 耐震等級3

- ✓ 損傷・機能に関するモニタリング技術を検証
- ✓ 地盤上の3階建て住宅を実験（耐震等級3）
- ✓ 地中配管設備，RC基礎を忠実に再現
- ✓ 住宅用システム機能を可能な限り充実
- ✓ 家具什器等を過不足なく設置

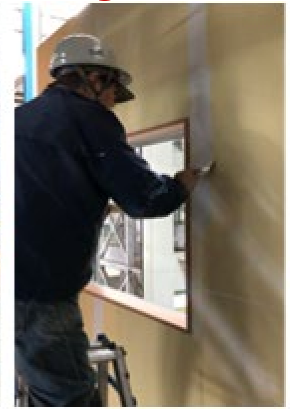


Requirement of connection reinforcement (2000), as a result, enhanced strength capacity double



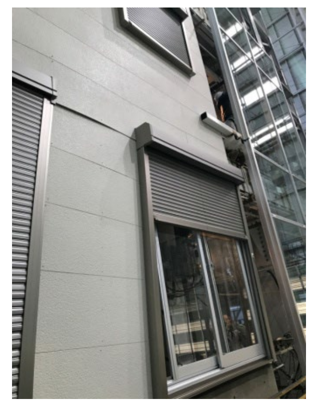
Preliminary exterior frame test
(Curtain wall company FUJI SASH)



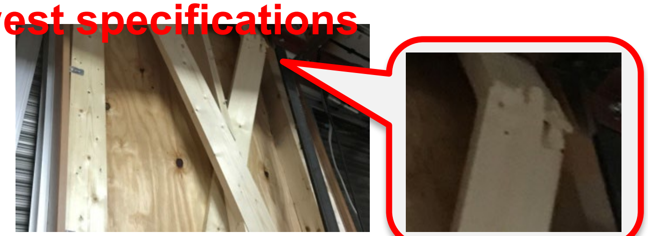



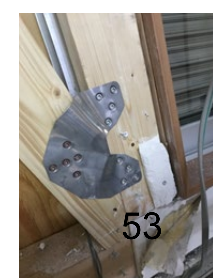

Extracted exterior frame; lower two stories



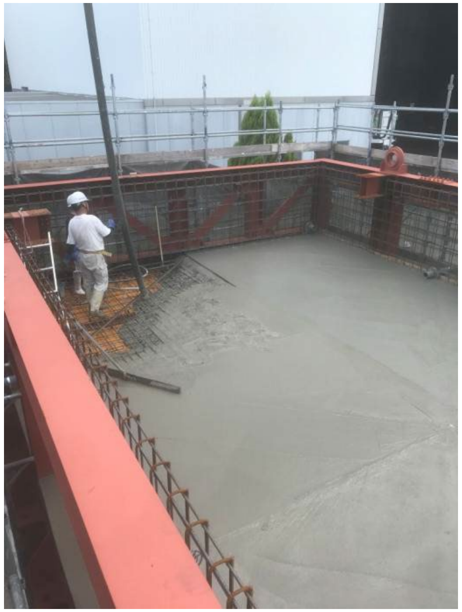


Damage procedure in case of post-beam frame having newest specifications



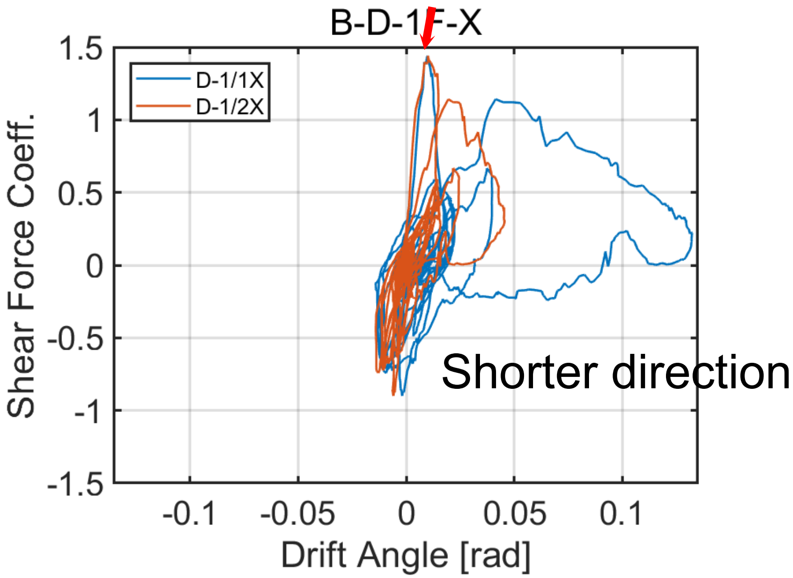


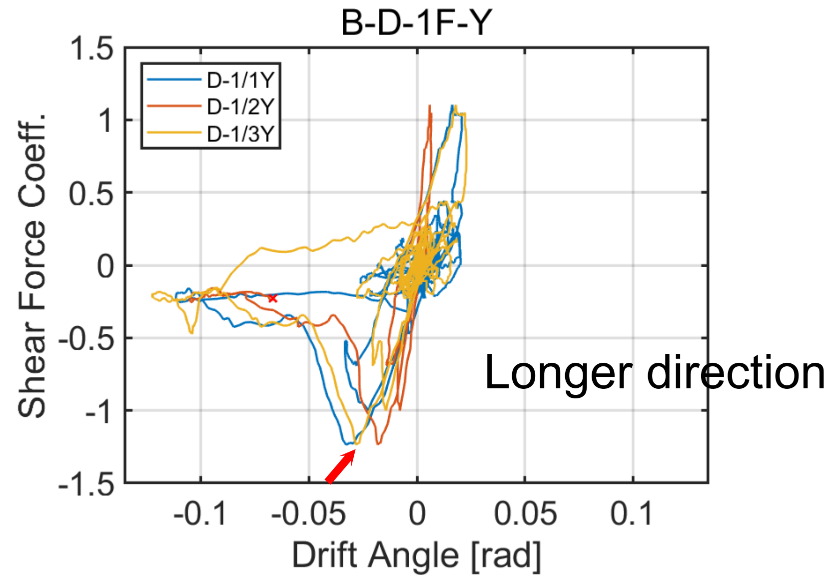
Real deep soil layer



First phase conducted in advance

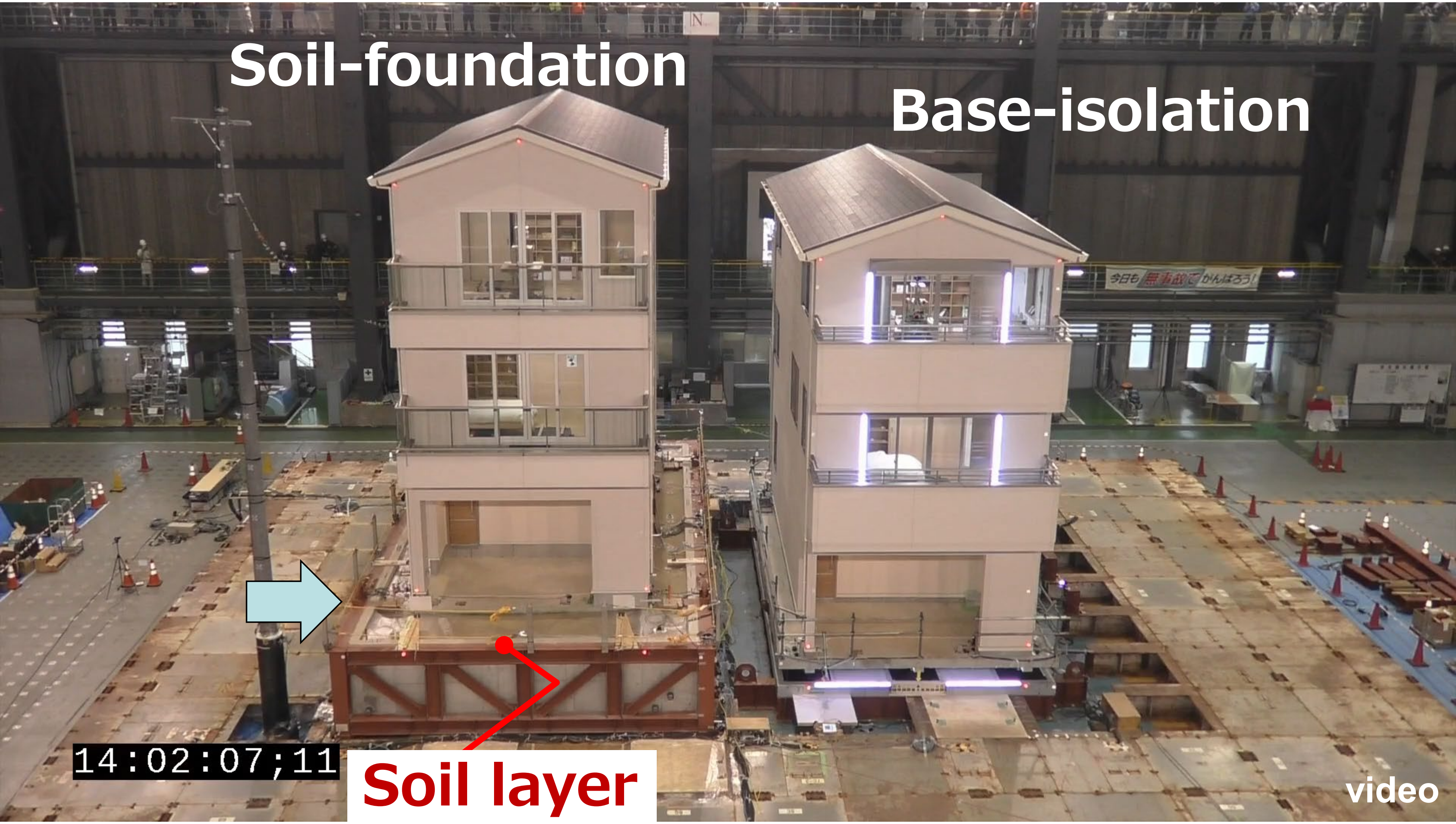
2019. 2. 12 (Phase 3) JMA Kobe100%



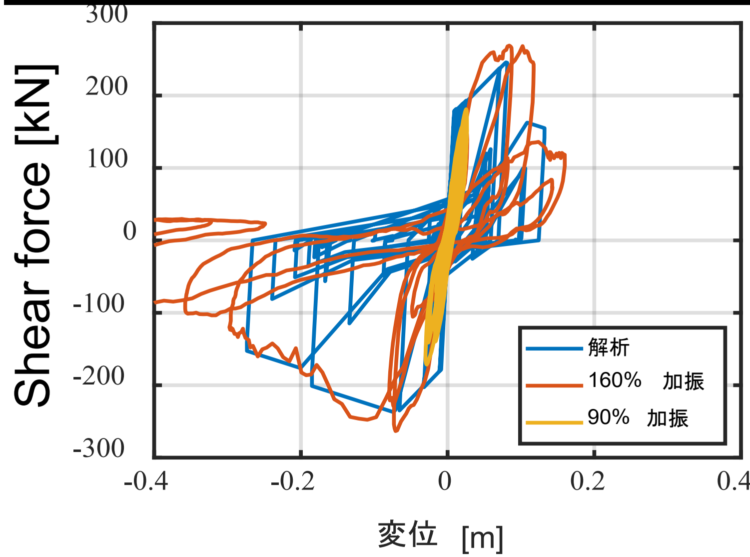


Firmly fixed foundation

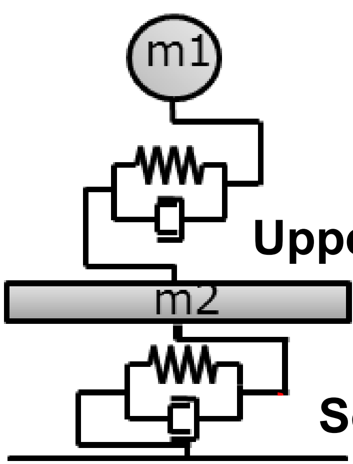
2019. 2. 1 (Phase 1)　JMA Kobe 100%



Sliding and Collapse; Statistical Approach

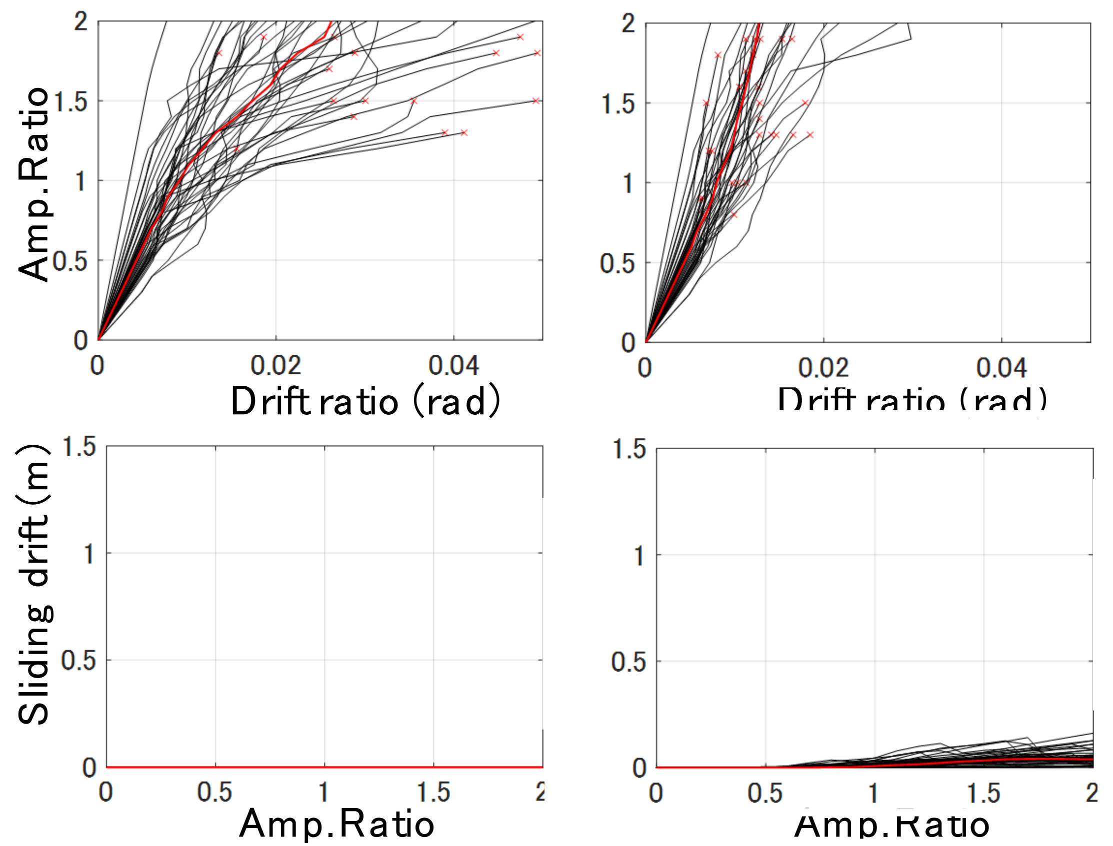


I-Krawinkler model



Upper Structure

Soil-Foundation



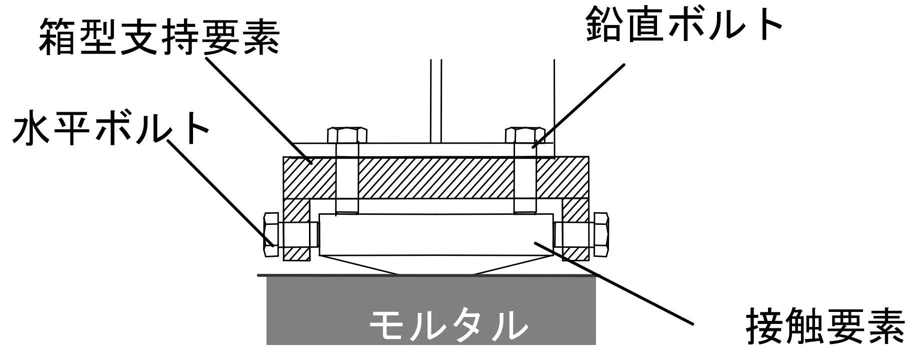
μ=0.80

μ=0.52

Friction tests in DPRI from 2007

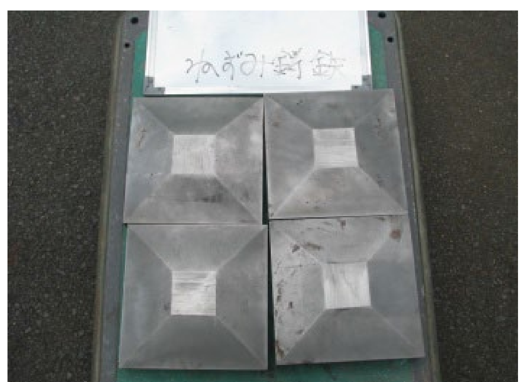
Kaken･Young (B)

Kaken･Young (A)



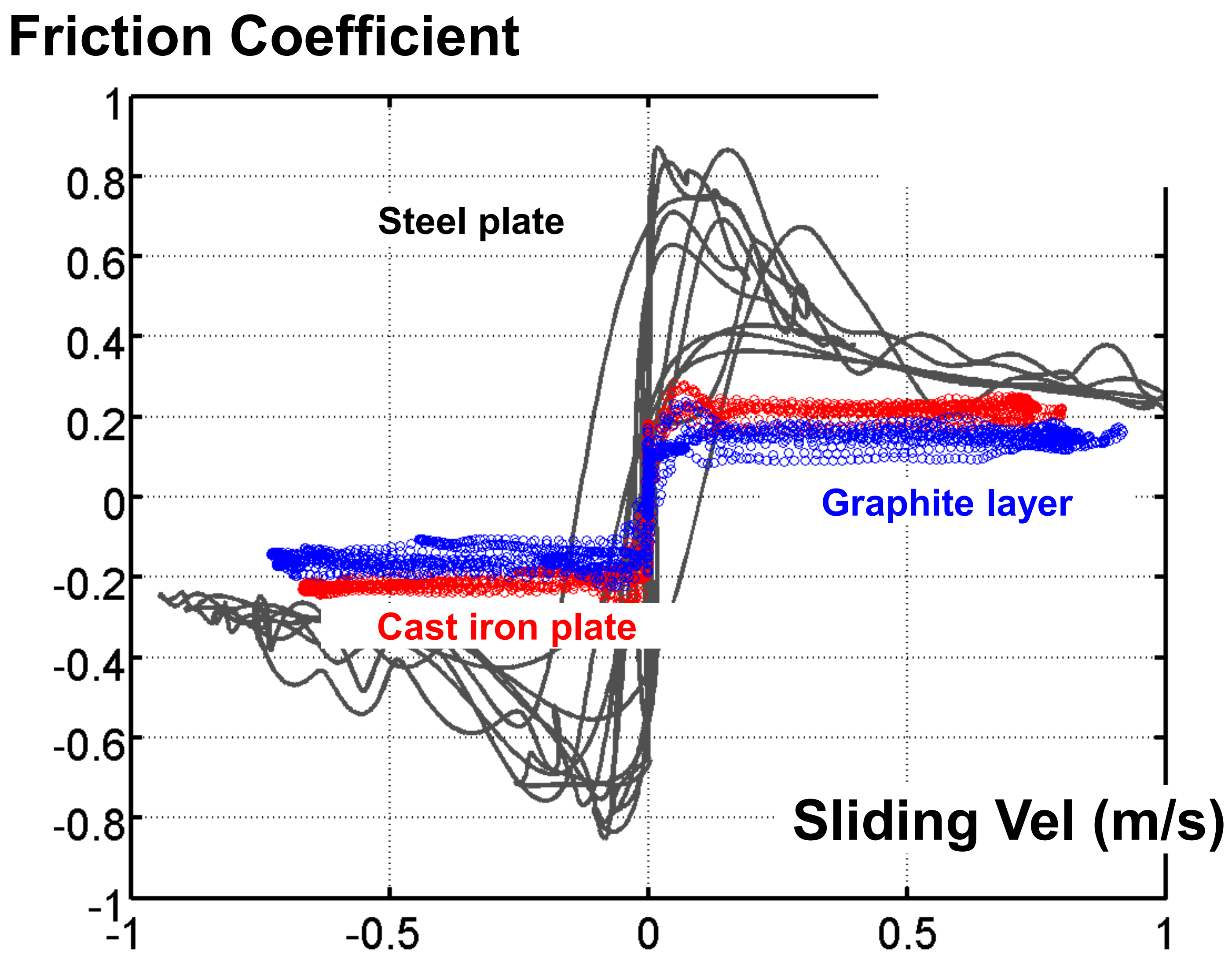
Steel

Cast iron



Mortar

Cast iron is sliding on mortar



JMA-Kobe 50%, Several centi-meter

JMA-Kobe 100%, A few hundreds centi-

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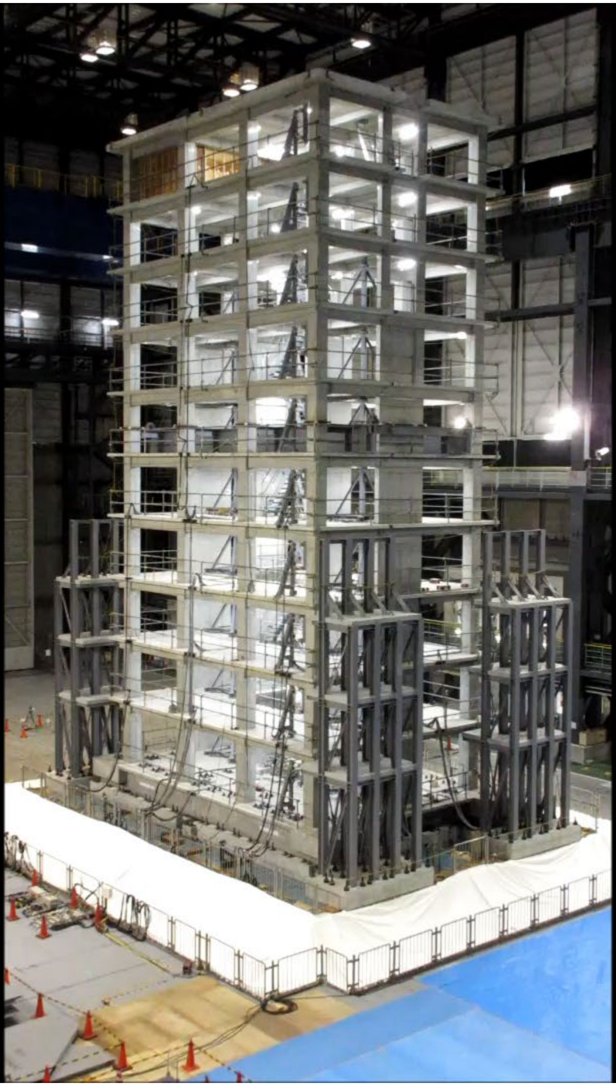
Current design code and JMA-Kobe 100%
⇒Stable global response



video

Beam-Column joint failure mode → Irreparable

Topics

1. High-rise building by substructure testing

2. Sensing technology with the industrial

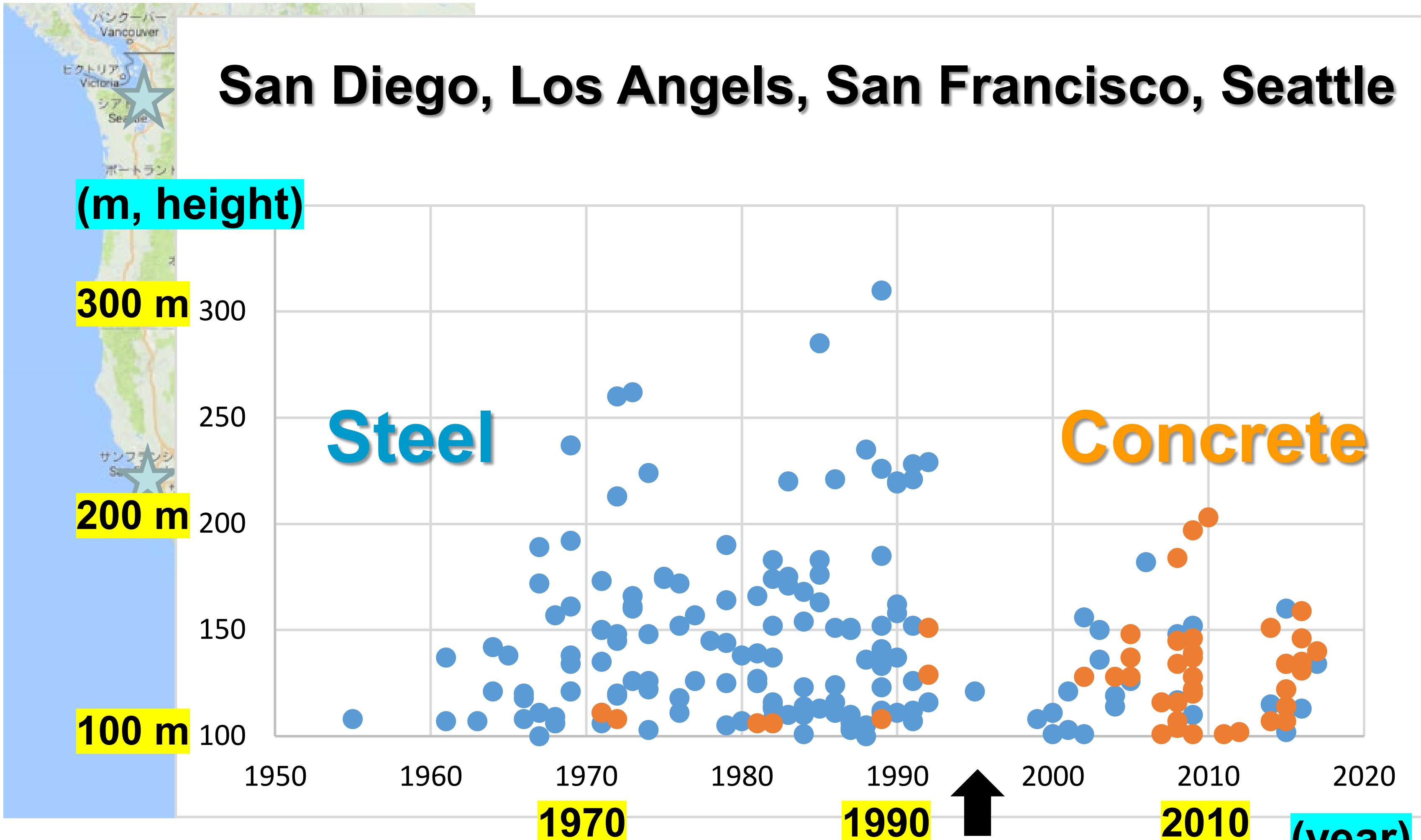
3. Soil structure interaction highly inelastic

4. **Detailed simulation with the industrial**

Higher than 100m

After the Northridge, 64 %

(Before the Northridge, 5%)



West Coast of US

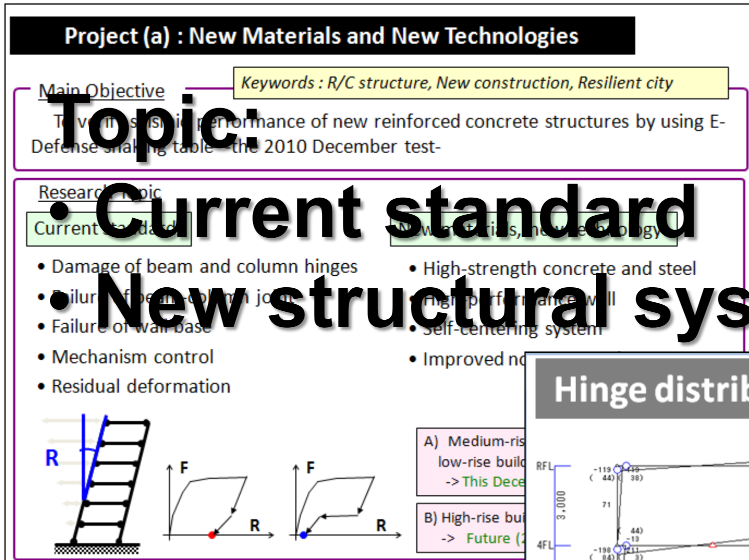
1994 Northridge Earthquake

Test preparation

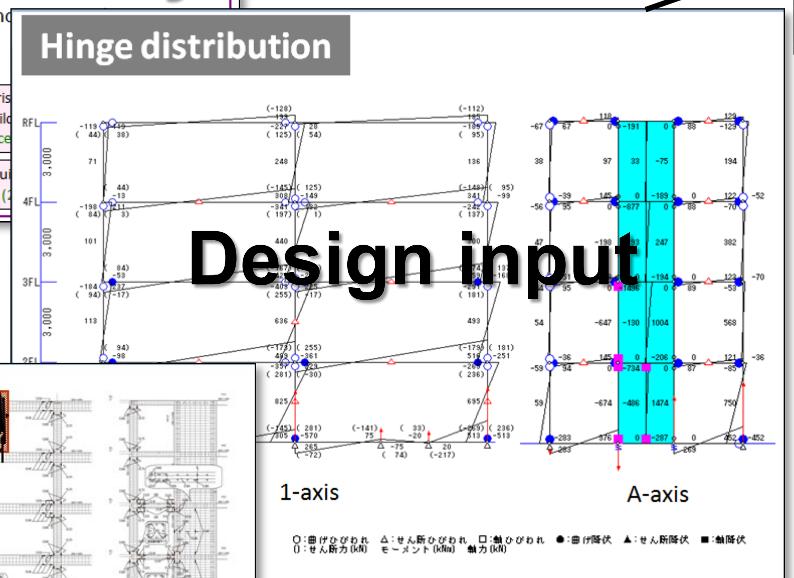
NEES/E-Defense cooperation

Topic:

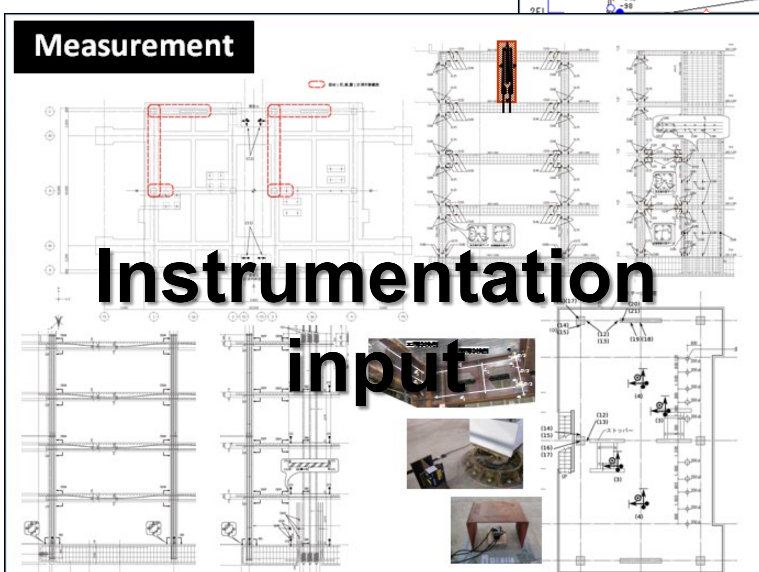
- Current standard
- New structural system



Design input



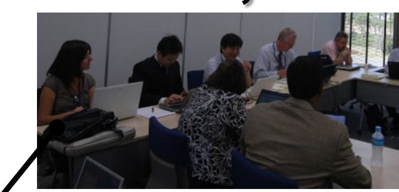
Instrumentation input



2009. September

2009, October

2010, March



2010, September

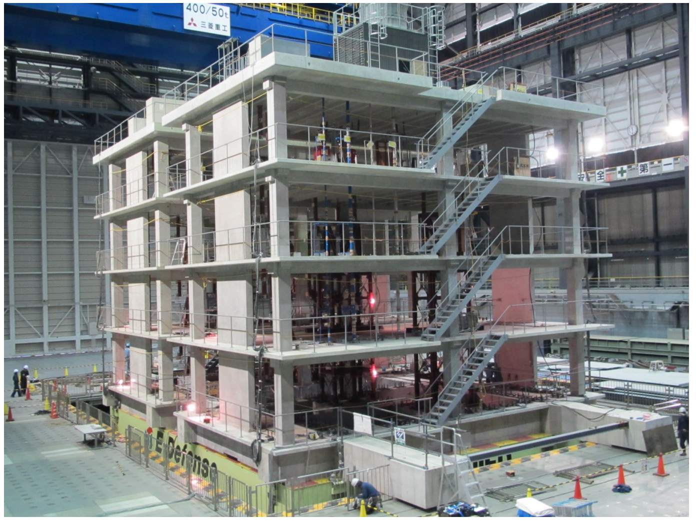
2010, December

PACIFIC EARTHQUAKE ENGINEERING
RESEARCH CENTER

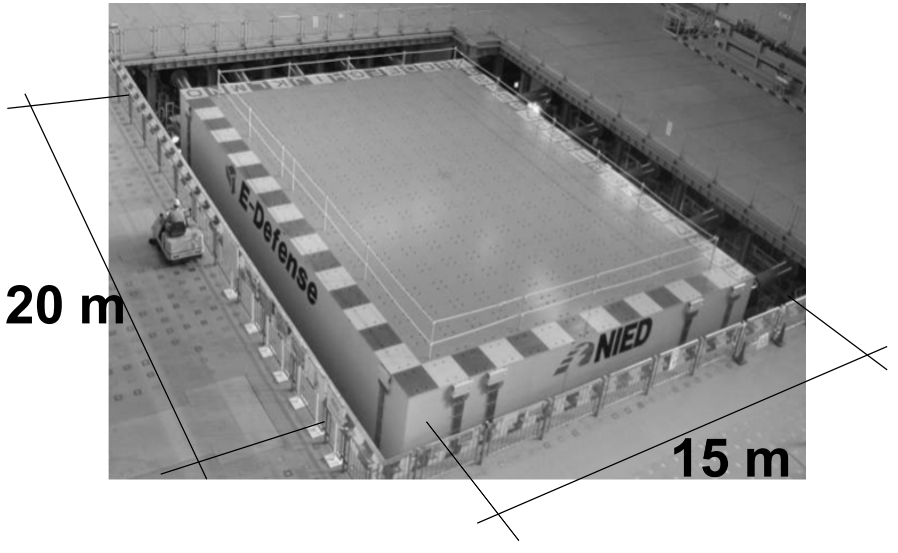
Design and Instrumentation of the 2010 E-Defense Four-Story Reinforced Concrete and Post-Tensioned Concrete Buildings

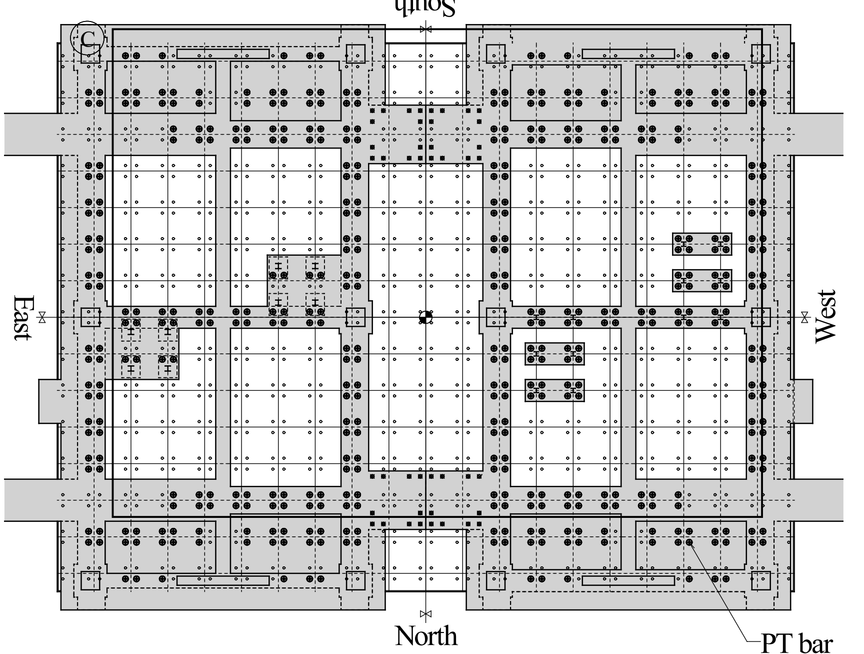
Takuya Nagae, Kenichi Tahara, Taizo Matsumori,
Hitoshi Shiohara, Toshimi Kabeyasawa,
Susumu Kono, Minehiro Nishiyama
(Japanese Research Team)
and
John Wallace, Wassim Ghannoum, Jack Moehle, Richard Sause,
Wesley Keller, Zeynep Tuna
(U.S. Research Team)

Setup of Twin Specimens



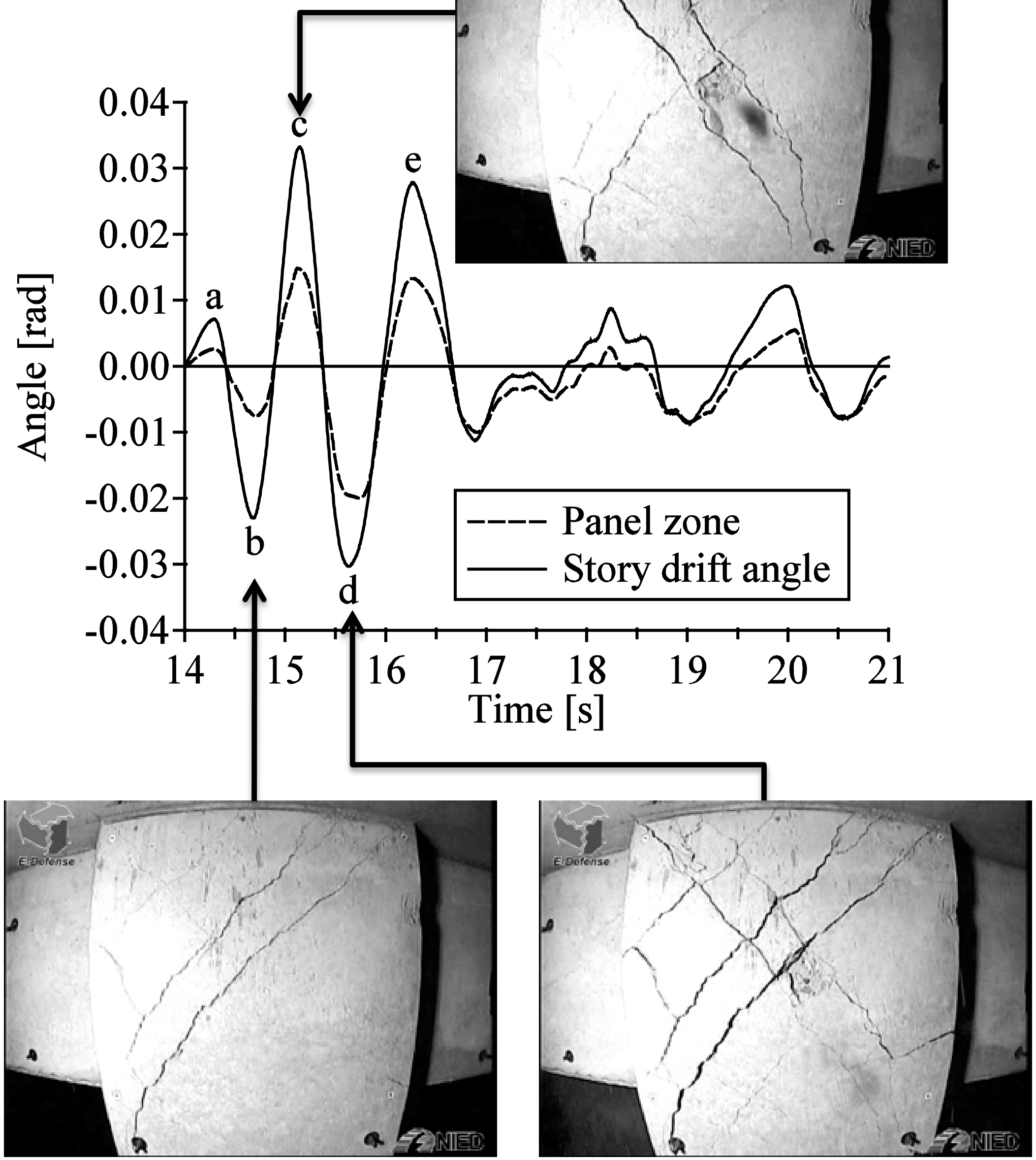
Twin building specimens were set up on the table.

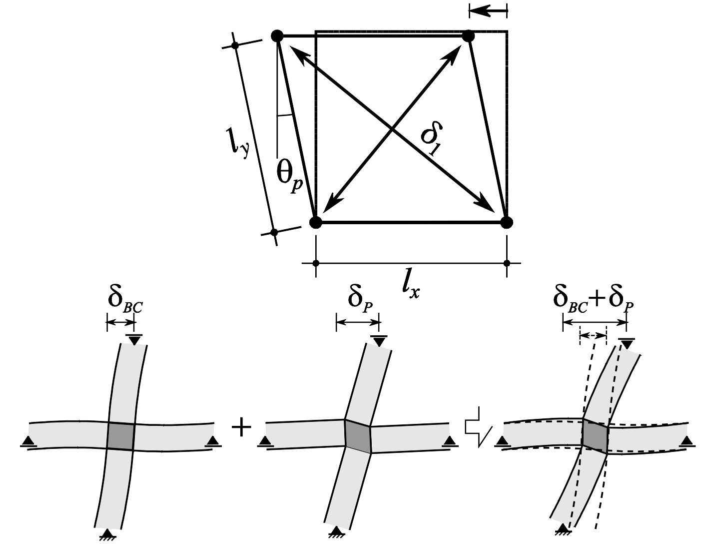


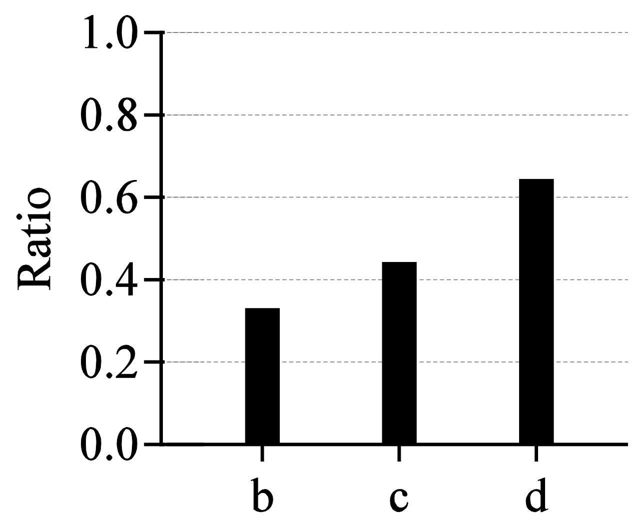


RC moment frame/ Beam-column joint

JMA-Kobe-100%

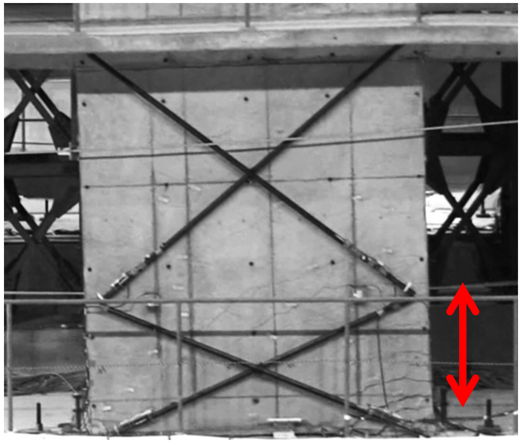






Ratio of shear deformation to story drift

RC wall frame/ The first story wall base



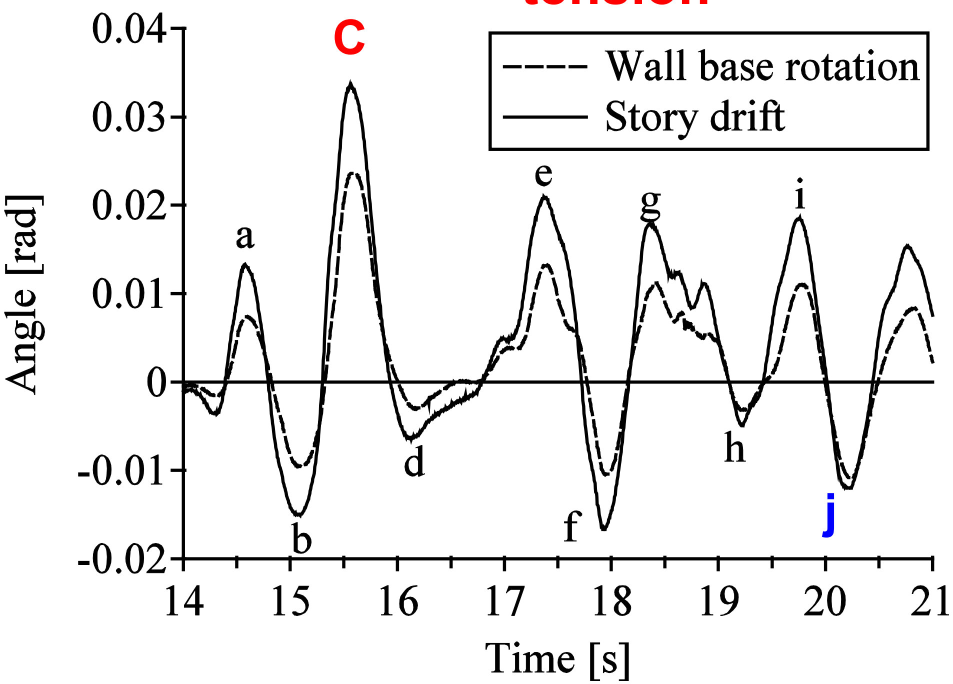
Significant elongation

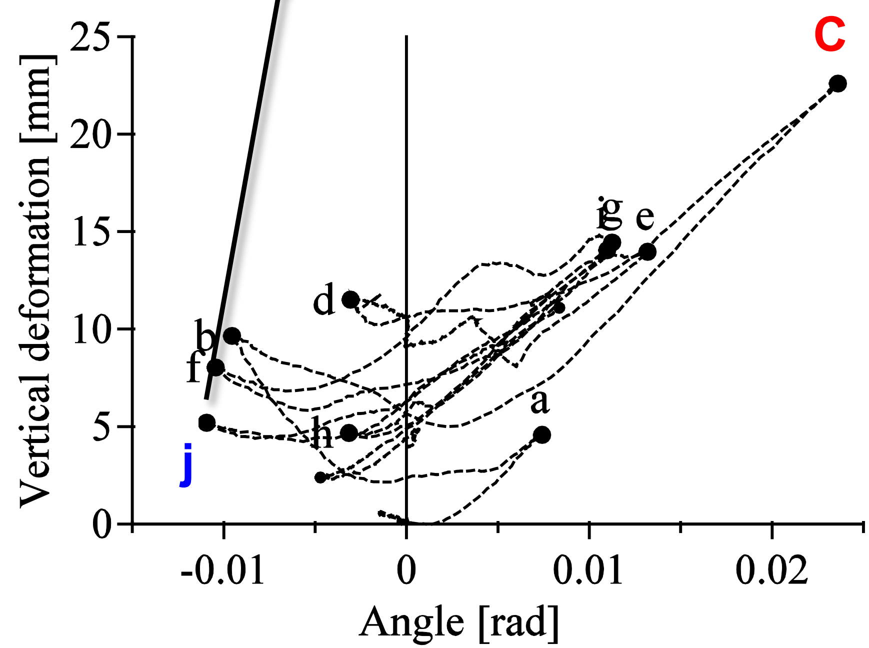
A-side

B-side

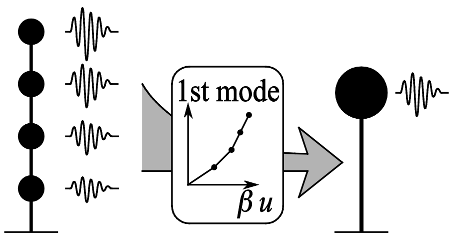
End zone in tension

B-side





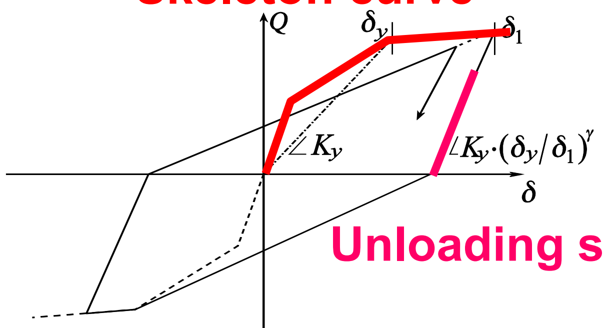
First mode response vs SDOF analysis



1st mode response at center of floor

(a) Test result

Skeleton curve



Unloading slope

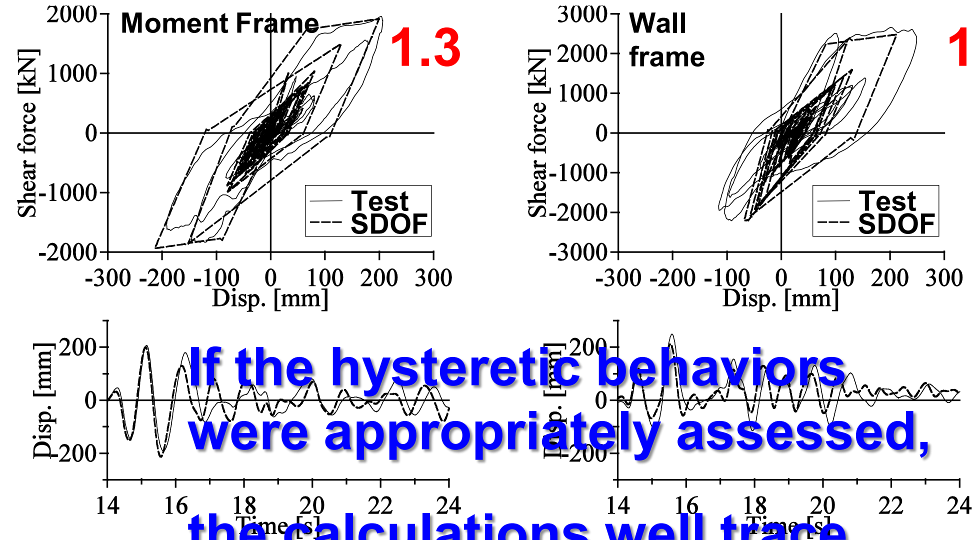
SDOF system based on Takeda model

(b) Dynamic response analysis

The fitted skeleton curve

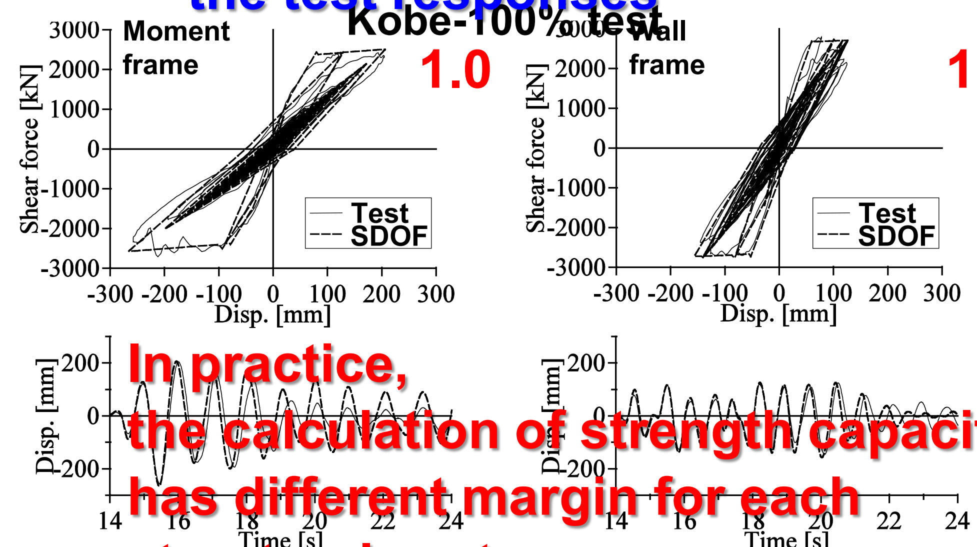
The fitted unloading slope

JMA-Kobe 100%



If the hysteretic behaviors were appropriately assessed, the calculations well trace the test responses

(d) Comparison of RC specimen (γ= -0.4) during JMA-Kobe-100% test

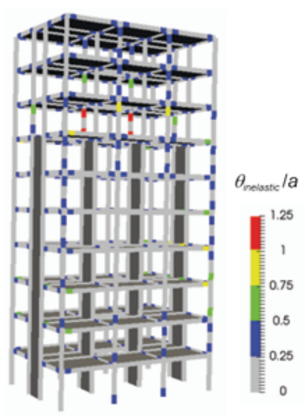


In practice, the calculation of strength capacity has different margin for each structural system.

(e) Comparison of PT specimen (γ= -0.9) during JMA-Kobe-100% test

ATC numerical simulation manual

NIST GCR 22-917-50



Benchmarking Evaluation Methodologies for Existing Reinforced Concrete Buildings

Applied Technology Council

This publication is available free of charge from:
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March 2022

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National Institute of Standards and Technology
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Participants

National Institute of Standards and Technology

Siamak Sattar, Acting Group Leader, Earthquake Engineering Group
Dustin Cook, NRC Post-doctoral Fellow, Earthquake Engineering Group
Steven L. McCabe, Associate Division Chief for Statutory Programs, Materials and Structural Systems Division
Engineering Laboratory
www.NEHRP.gov

Applied Technology Council

201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065
www.ATCouncil.org

Program Management

Jon A. Heintz (Program Manager)
Ayse Hortacsu (Associate Program Manager)

Program Committee on Seismic Engineering

Jon A. Heintz (Chair)
Michael Cochran
James R. Harris
James Jirsa
Roberto Leon
Stephen Mahin
James O. Malley
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Insung Kim
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Abbie Liel
Laura Lowes
Adolfo Matamoros
Farzad Naeim
Rob Smith
John Wallace

Working Group Members

Saman A. Abdullah
Tarbin Basnet
Travis Chrupalo
Alex Chu
Dustin Cook
Ariel Creagh
John A. Egan
Hamid Khodadadi
Kristijan Kolozvari
Ali Roufegarinejad
Andrew Sen

Project Review Panel

Brian Kehoe
Santiago Pujol
Peter Somers
Daniel Zepeda

Modeling verification, given OpenSees

Chapter 4

Four-story Frame and Wall Test Structure

4.1 Overview

This chapters presents benchmarking studies for a 4-story reinforced concrete structure tested on the E-Defense shake table in Japan in 2010, shown in Figure 4-1. Ground motion records and response parameters are available since the structure was tested on a shake table. In this chapter, computed responses for analytical models and predicted damage are compared with measured responses and observed damage for strong motion records from Southern Hyogo Prefecture Earthquake of January 17, 1995.

Figure 4-1 Two structures tested at E-Defense shake table, study structure is on the left side of the photo. (Nagae et al., 2015).

The structure was evaluated in accordance with the nonlinear and linear dynamic procedures of ASCE 41-17. Nonlinear models were developed using OpenSees and Perform3D software with nonlinear and linear elastic joint elements. Linear models were developed using ETABS software. The models were constructed per details presented in Appendix A, unless otherwise noted.

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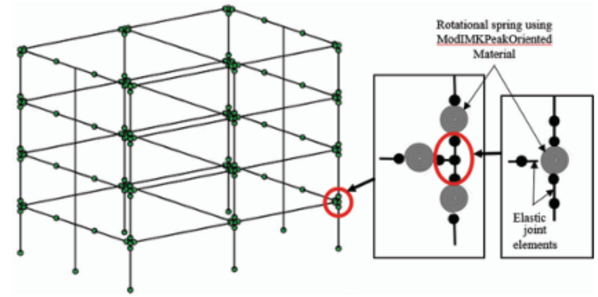

Figure 4-12 OpenSees LP model with material model listed for the nonlinear zero-length springs.

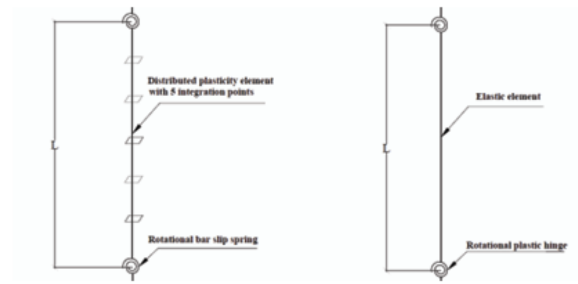

Figure 4-13 Element topology for fiber section (left) and lumped plasticity (right) models.

For the fiber section elements, sections were discretized and assigned material models Concrete02 for unconfined concrete in the column and wall cover and wall web, Concrete04 for confined concrete in the column core and wall boundary elements, and Steel 02 for reinforcing bars. Basic parameters of the stress-strain curve for concrete in compression were calculated using the model by Mander et al. (1988a). The stress-strain relationship (Figure 4-15) was regularized to prevent localized deformations after concrete entered the descending branch of the stress-strain curve. Strain at 20% of the peak stress was calculated using the relationship proposed by Coleman and Spacone (2001) for constant fracture energy:

$$\varepsilon_{20} = \frac{G_f^c}{0.6 f'_c L_p} - \frac{0.8 f'_c}{E_c} + \varepsilon_0 \qquad \text{Eq. 4-1}$$

The 2015 and 2018 ten-story structures

Chapter 5

Ten-story Frame and Wall Test Structure

5.1 Overview

This chapter presents benchmarking studies for a 10-story reinforced concrete structure tested at the E-Defense shake table in Japan in 2015 (Nagae et al., 2015), shown in Figure 5-1. Ground motion records and response parameters are available since the structure was tested on a shake table. In this chapter, computed responses for nonlinear models of the building and predicted damage are compared with measured responses and observed damage for strong motion records from Southern Hyogo Prefecture Earthquake of January 17, 1995.

Figure 5-1 10-story structure tested at E-Defense shake table in 2015 (photo courtesy of J. Wallace).

The structure was evaluated in accordance with the nonlinear dynamic procedures of ASCE 41-17 and ACI 369.1-17, *Standard Requirements for Seismic Evaluation and Retrofit of Existing Concrete Buildings and Commentary* (ACI, 2017). For the evaluation of wall elements, proposed updates for the ASCE 41-23 wall modeling parameters have been included. Nonlinear models were developed using OpenSees and Perform3D software with nonlinear wall, beam, and column elements, and with nonlinear and linear elastic joint elements. The models were constructed per details presented in Appendix A, unless otherwise noted.

This chapter also provides results of a fragility analysis showing the collapse

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Axial loads used in calculating ASCE 41-17 modeling parameters for joints and acceptance criteria for all structural elements were obtained as the maximum compressive axial demands developed in each element from a pushover analysis of the building out to initiation of loss of lateral load carrying capacity using a first mode lateral load distribution. Slab out-of-plane bending was not modeled explicitly but was rather accounted for through effective flange widths assigned to the beams.

The maximum compressive axial load (due to gravity load and earthquake effects) did not exceed 16% of the column gross sectional capacity, $A_g f'_c$, throughout the height of the building. Typically, the moment frame columns in the bottom six stories had axial loads greater than $0.1A_g f'_c$. It is noted the modeling parameters are computed for maximum compression axial load determined from pushover analysis using the first mode lateral load distribution, whereas column yielding generally occurred during the analysis at minimum axial load; therefore, the reported ratios for columns are likely on the conservative side. All columns were expected to respond primarily in flexure as they had relatively high levels of confinement, such that their shear strength exceeded the shear demand associated with flexural hinging by a significant margin. Therefore, gross elastic shear stiffness was used for frame members, as recommended by ASCE 41-17.

All beams were likewise expected to respond primarily in a flexure mode. Beam sections included an effective flange width determined based on ASCE 41-17 Section 10.3.1.3 (Figure 5-12). A biaxial mesh was used to model beams and columns, as shown in Figure 5-12.

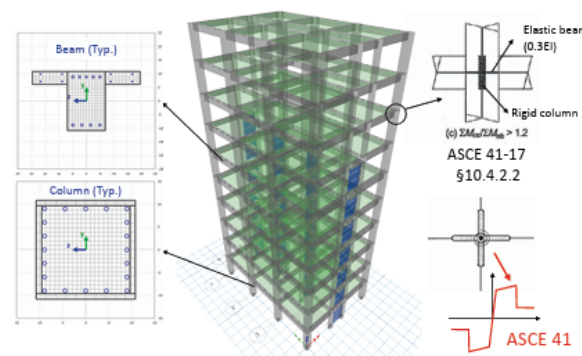

Figure 5-12 Moment frame element modeling approaches.

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Nonlinear Response Prediction of a Four-story Reinforced Concrete Building Tested at the E-defense Shake Table

Swarup Ghosh, ZURU Tech
Farhad Dashti, ZURU Tech
Takuya Nagae, Nagoya University
Tatsuya Asai, University of Tokyo
Hiroshika Uta, Nagoya University

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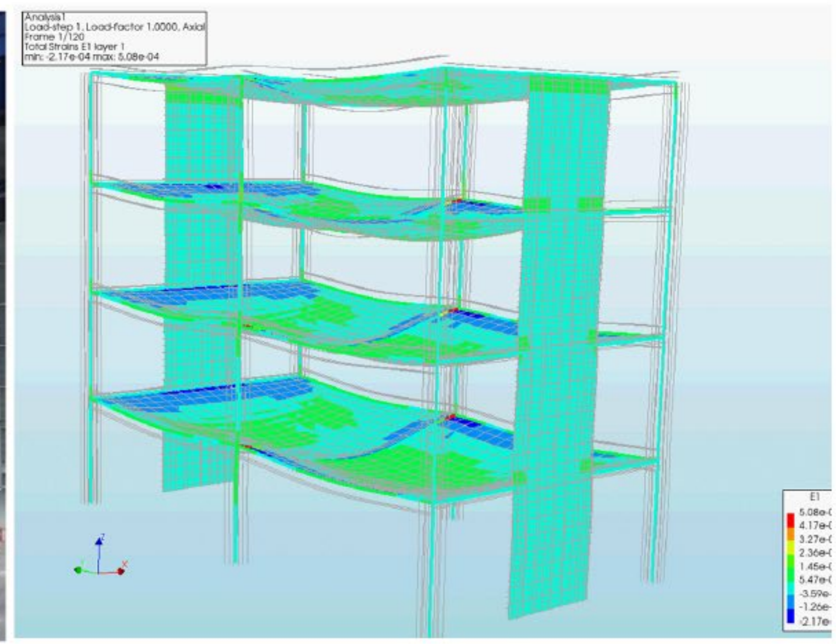
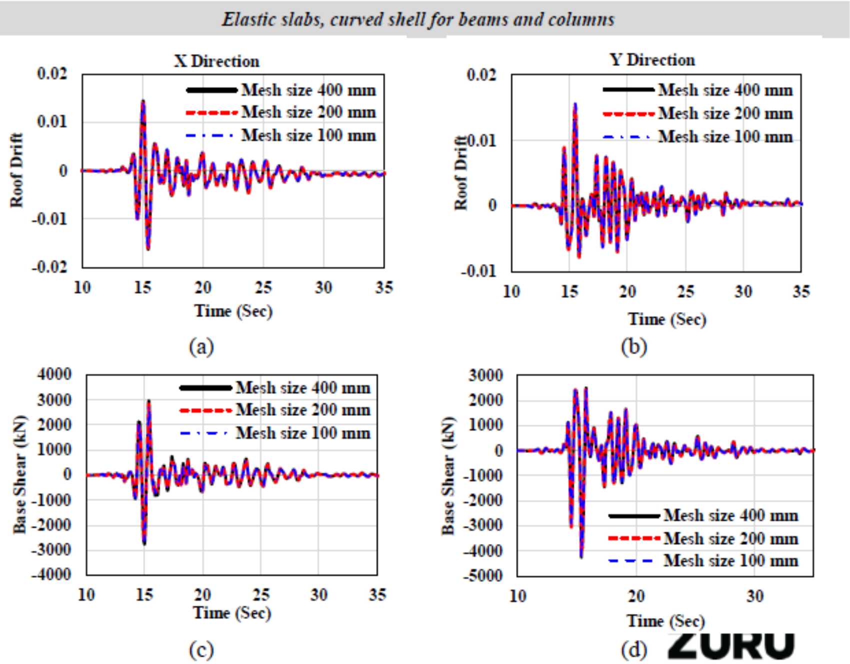


Nagae, T., et al. "Design implications of large-scale shake-table test on four-story reinforced concrete building." ACI Structural Journal 112.2 (2015): 135.

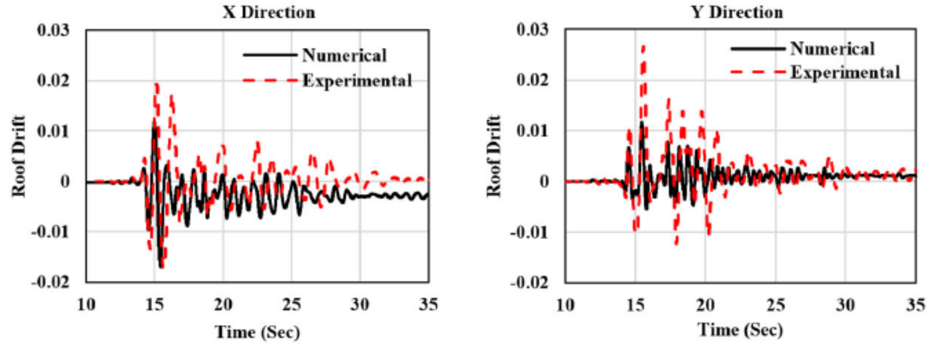
Mesh sensitivity

Comparison of modal time periods

Modes	400 mm mesh	200 mm mesh	100 mm mesh
1	2.5838	2.5667	2.5524
2	3.2337	3.2107	3.1938
3	3.8065	3.7797	3.7599
4	8.0497	7.9956	7.9524
5	14.041	13.943	13.857



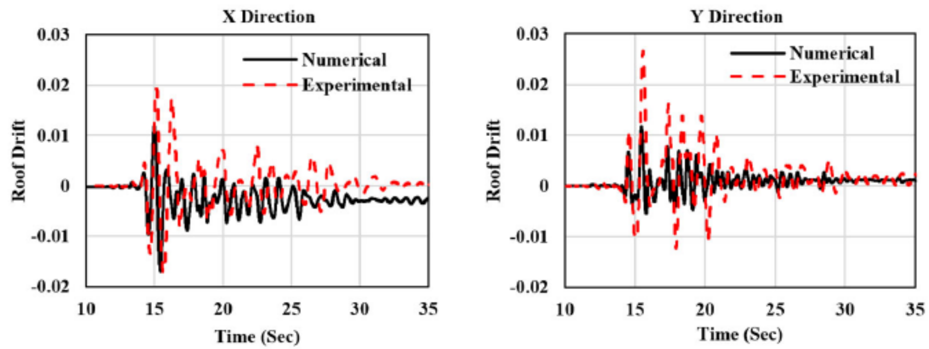
Elastic slabs, class III beam elements for beams and columns



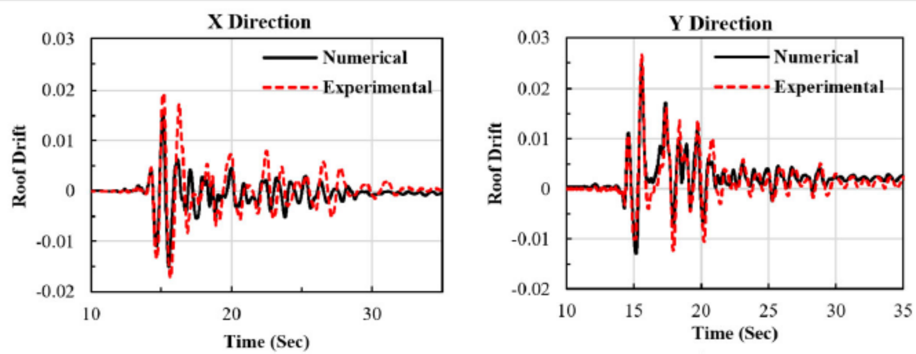
Drift history; Linear elastic vs nonlinear inelastic slabs

Drift history; Linear elastic vs nonlinear inelastic slabs

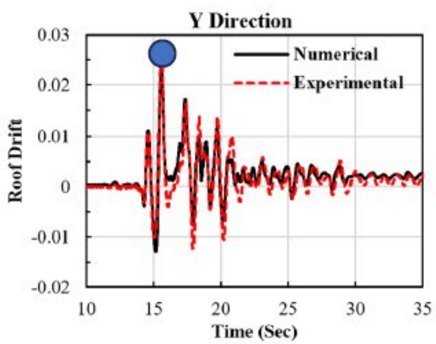
Elastic slabs, class III beam elements for beams and columns

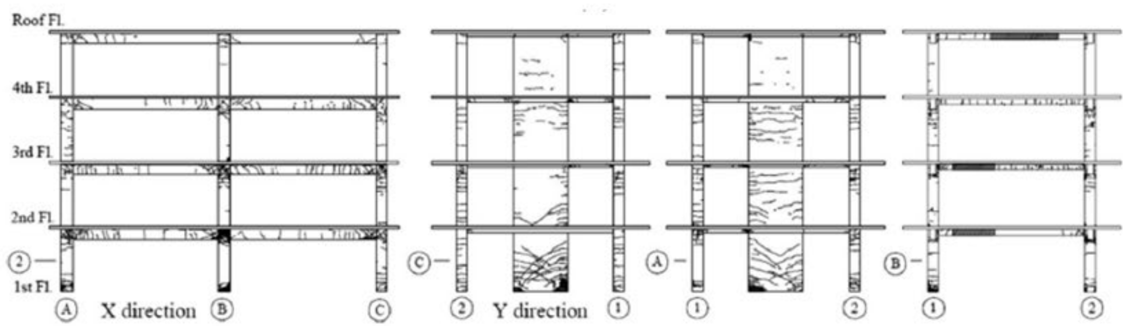


Nonlinear slabs, curved shell for beams and columns

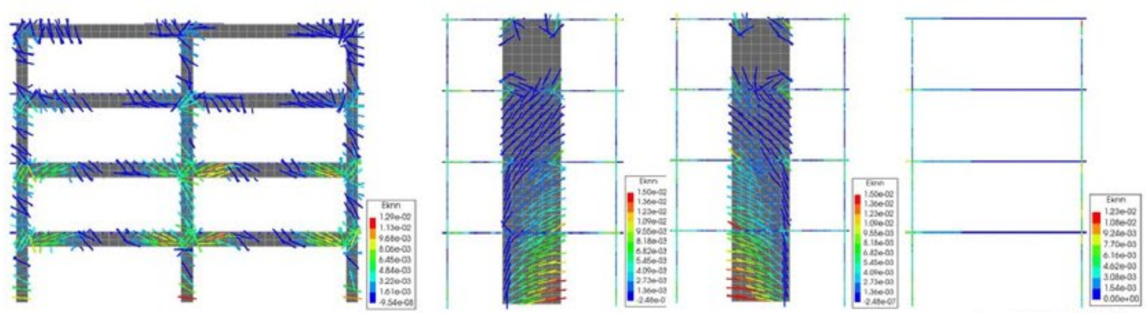


Crack pattern;





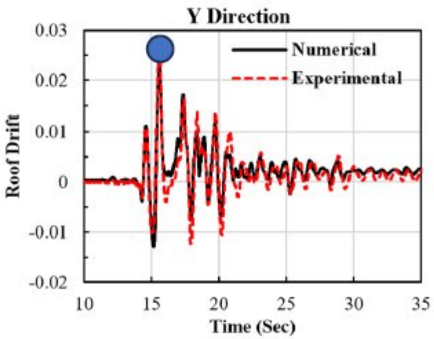
Experimental observation

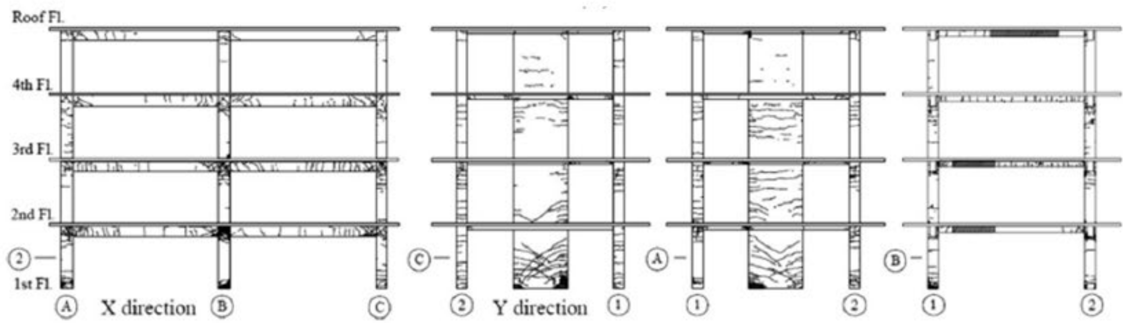


Numerical simulation

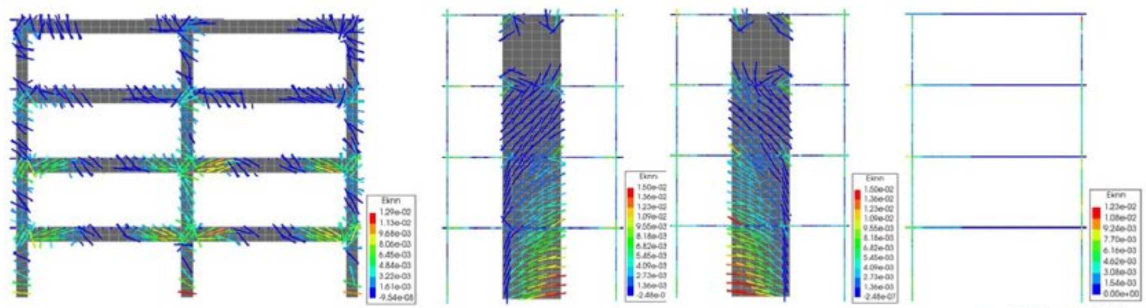
ZURU

Crack pattern;





Experimental observation



Numerical simulation

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NONLINEAR RESPONSE PREDICTION OF A FOUR-STORY REINFORCED CONCRETE BUILDING TESTED AT THE E-DEFENSE SHAKE TABLE

S. Ghosh[1], F. Dashti[1], T. Nagae[2], T. Asai[3] & H. Uta[2]

[1] ZURU Tech HK Ltd, Tsim Sha Tsui, Hong Kong
[2] Nagoya University, Nagoya, Japan
[3] University of Tokyo, Tokyo, Japan

Engineering Structures 306 (2024) 117769

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Numerical simulation of the 2010 4-story reinforced concrete structure tested on the E-defense shake table

Swarup Ghosh[a,*], Farhad Dashti[a], Takuya Nagae[b], Hiroshika Uta[b]

[a] ZURU Tech HK Ltd, Tsim Sha Tsui, Hong Kong
[b] Nagoya University, Nagoya 464-8601, Japan

ZURU

Journal papers

Numerical simulation of the 2010 4-story reinforced concrete structure tested on the E-defense shake table
Ghosh, S; Dashti, F; Nagae, T; Uta, H
ENGINEERING STRUCTURES　306 巻　2024年5月

Damage inference and residual capacity assessment for an E-Defense 2018 ten-story RC test structure
Zhuang, YC; Ji, XD; Sun, L; Kajiwara, K; Kang, JD; Nagae, T
ENGINEERING STRUCTURES　302 巻　2024年3月

Shaking-table test results of a full-scale free-standing building with base sliding and rocking
Kang, JD; Kajiwara, K; Tosauchi, Y; Sato, E; Inoue, T; Kabeyasawa, T; Shiohara, H; Nagae, T; Kabeyasawa, T; Fukuyama, H; Mukai, T
EARTHQUAKE ENGINEERING & STRUCTURAL DYNAMICS　52 巻 (10) 頁: 3008 - 3029　2023年8月

Full-scale shaking table experiments on the seismic response of a 10-story reinforced-concrete building: overview and analysis
Kang, JD; Kajiwara, K; Nagae, T; Sato, E; Tosauchi, Y
BULLETIN OF EARTHQUAKE ENGINEERING　2023年7月

[Shaking table tests of a full-scale 10-story reinforced-concrete building (2015). Phase II: Seismic resisting system]
Kang Jae-Do, Kajiwara Koichi, Tosauchi Yusuke, Sato Eiji, Inoue Takahito, Kabeyasawa Toshimi, Shiohara Hitoshi, Nagae Takuya, Kabeyasawa Toshikazu, Fukuyama Hiroshi, Mukai Tomohisa
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Kabeyasawa Toshikazu, Kabeyasawa Toshimi, Xiongjie Cheng, Kang Jae-do, Nagae Takuya, Kajiwara Koichi
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[Nonlinear modeling of the ten-story RC building structure of 2015 E-Defense shaking table tests]
Sun Lei, Ji Xiaodong, Zhuang Yuncheng, Kajiwara Koichi, Kang Jae-Do, Nagae Takuya
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Seismic responses of a free-standing two-story steel moment frame equipped with a cast iron-mortar sliding base
Chung Yu-Lin, Kuo Kuan-Ting, Nagae Takuya, Kajiwara Koichi
EARTHQUAKES AND STRUCTURES　17 巻 (3) 頁: 245-256　2019年9月

Shake table test of a full-scale four-story reinforced concrete structure and numerical representation of overall response with modified IMK model
Yenidogan Cem, Yokoyama Ryo, Nagae Takuya, Tahara Kenichi, Tosauchi Yusuke, Kajiwara Koichi, Ghannoum Wassim
BULLETIN OF EARTHQUAKE ENGINEERING　16 巻 (5) 頁: 2087-2118　2018年5月

Seismic Damage Reduction of a Structural System based on Nontraditional Sliding Interfaces with Graphite Lubrication
Enokida Ryuta, Nagae Takuya
JOURNAL OF EARTHQUAKE ENGINEERING　22 巻 (4) 頁: 666-686　2018年

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Shake-Table Test of a Full-Scale 4-Story Precast Concrete Building. II: Analytical Studies
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JOURNAL OF STRUCTURAL ENGINEERING　143 巻 (6)　2017年6月

DESIGN IMPLICATIONS OF A LARGE-SCALE SHAKING TABLE TEST ON A FOUR-STORY REINFORCED CONCRETE BUILDING
T. Nagae, W. M. Ghannoum, J. Kwon, K. Tahara, K. Fukuyama, T. Matsumori, H. Shiohara, T. Kabeyasawa, S. Kono, M. Nishiyama, R. Sause, J. W. Wallace, and J. P. Moehle
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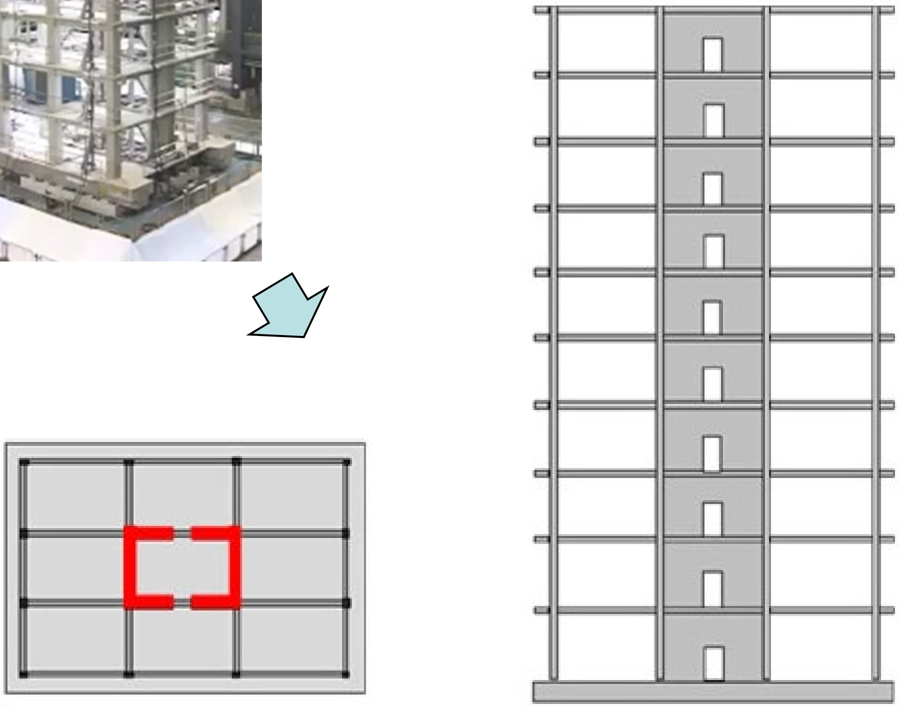
Core wall and MRF dual system of high-rise building

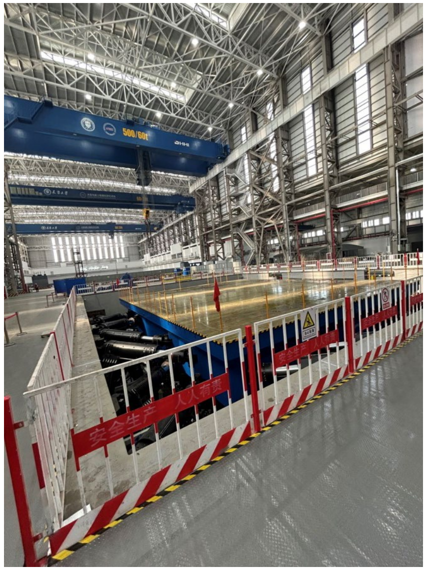
→ Widely adopted in the current practice

→TEST VERIFICATION was highly required

Meeting in 2019



New collaboration based on NFEES, Tianjin University



March 13-14, 2024

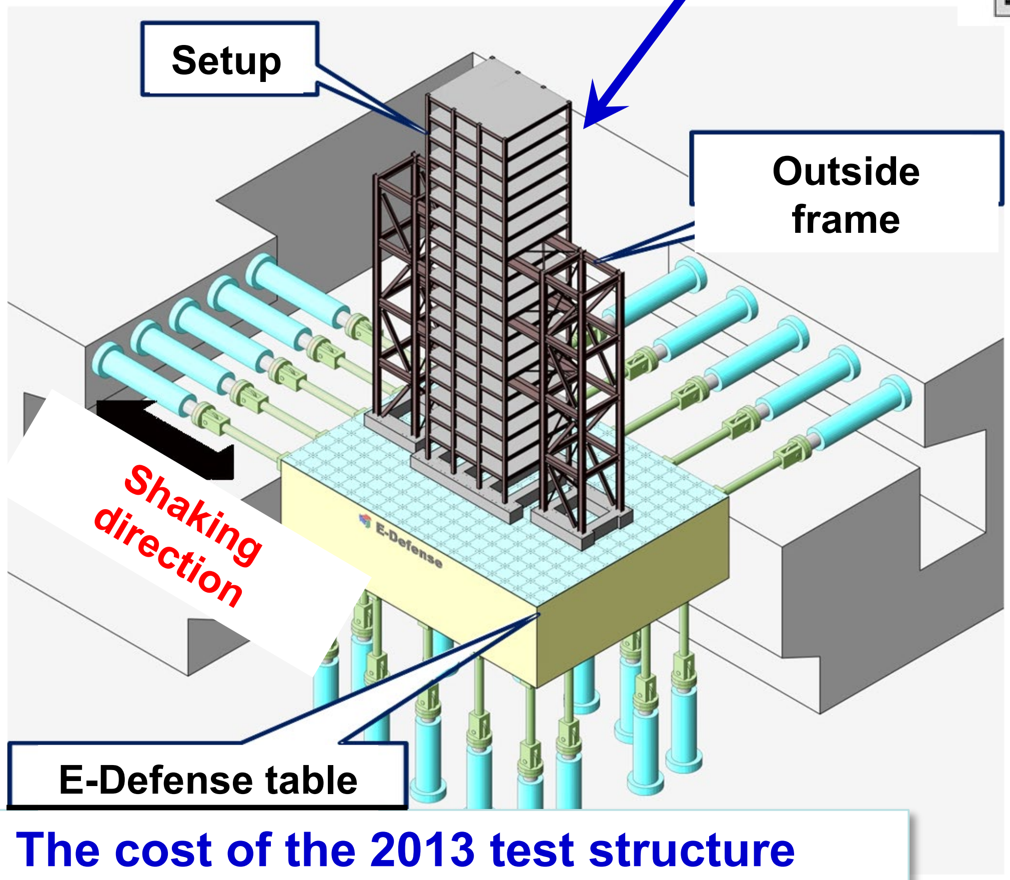
Option2: 50% scale high-rise test structure

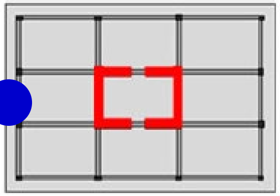
Three six-story partial frames were assembled in series
→ Collapse capacity would be the target
→ The construction cost will be lower than the Option 1.
→ This 2013 steel test is the reference.

Design→ RC Test Structure and Input Motions

Final stage of the 2013 test

Replaced by RC structure





The cost of the 2013 test structure was reasonable

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RESEARCH ARTICLE

Earthquake Engineering and Resilience WILEY

Comprehensive wood dwelling tests for Post-and-Beam and Shear-Wall structures reflecting foundation boundaries

Kazuki Takaya[1] | Kazuto Ota[1] | Cem Yenidogan[2] | Takehiro Takahashi[3] | Shohei Yamada[4] | Hisatoshi Kashiwa[5] | Yosuke Kawamata[6] | Kazuhiro Hayashi[7] | Takuya Nagae[8]

[1]Graduate School of Environmental Studies, Nagoya University, Nagoya-shi, Aichi-ken, Japan

[2]Department of Civil Engineering, Yildiz Technical University, Istanbul, Turkey

[3]ICHIJO Co., Ltd., Shizuoka, Japan

[4]NIKKEN SEKKEI Ltd., Tokyo, Japan

[5]Graduate School of Engineering, Osaka University, Osaka, Japan

[6]National Research Institute for Earth Science and Disaster Resilience (NIED), Ibaraki, Japan

[7]Graduate School of Engineering, Chiba University, Chiba, Japan

[8]Disaster Mitigation Research Center, Nagoya University, Nagoya-shi, Aichi-ken, Japan

Correspondence
Takuya Nagae, Disaster Mitigation Research Center, Nagoya University, Furo-cho, Chikusa-ku, Nagoya-shi, Aichi-ken, Japan.
Email: nagae.takuya.h9@f.mail.nagoya-u.ac.jp

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Abstract

This paper focuses on the ultimate state of three-story wood dwellings with high aspect ratios, which are increasing in Japan's urban areas. Using shaking table test results from the 2019 full-scale shaking table test, a comprehensive study is conducted on the accuracy of evaluating ultimate state through the story shear failure mode at the first story, the tension fracture mode at the wall base of the first story, and foundation sliding mode on the soil. Methods evaluating the dynamic response behaviors of the building systems are also investigated. In the test, the current Japanese seismic design guidelines were applied, and two Grade-3 buildings were prepared. One adopted the Post-and-Beam structure (A-building), and the other the Shear-Wall structure (B-building). A series of tests planned very different physical boundary conditions surrounding their reinforced concrete (RC) mat foundations. The sills, column bases and wall bases of the upper wood structures were anchored to the RC foundations by steel anchor bolts, according to the current Allowable Stress Design (ASD) requirements. In the first stage, A-building equipped a Base-Isolation system, while B-building represented a generic foundation constructed on a 1.5 m-height real soil ground by preparing a rigid soil box (Foundation-Soil system). In the second stage of A-building and B-building, the foundation was firmly fixed (Fixed-Foundation system), and shaking table motions were fully applied to the foundations. The entire test system was setup on the large shaking table facility at E-Defense, and a series of tests were conducted using JMA-Kobe motion and JR-Takatori motion recorded in the 1995 Kobe earthquake as Maximum-Considered-Earthquake motions. Confirmed was the change in the structural mechanism due to the upper structural systems and the foundation boundaries. Regarding the upper