Masayoshi Nakashima

Professor Emeritus, Kyoto University
President, Kobori Research Complex
Counselor, Kajima Corporation

Masayoshi Nakashima - Areas of Research

Online Hybrid Testing

契機となった学習（1980年代前半）
オンライン応答実験法における実験誤差問題（1980年代）
サブストラクチャ法を使ったオンライン応答実験法（1980年代、2000年代）
リアルタイムオンライン応答実験の開発（1990年代）
オンライン応答実験の汎用化（2000年代）

Large-Scale Shaking Table Test

サブストラクチャ振動台実験法の開発（超高層への適用）（2000年代後半）

Ductility of Steel Beams & Connections (1995 Kobe)

兵庫県南部地震被害調査（19990年代中盤）
鋼構造溶接柱梁接合部の耐震性能と破断（1990年代）
鋼構造部材と骨組の完全崩壊挙動の再現（2000年代）

Seismic Protective Devices/Elements

低降伏点鋼を用いた耐震壁の履歴性能（1990年代）
セフルセンタリング機構を持つ部材と骨組の開発（2000年代）
免震病院の機能性保持能力（2000年代～2010年代）

Application of New Steel Materials

H-SA780鋼を用いた無溶接構造（2000年代～2010年代）
鋼繊維補強モルタルを用いた鋼とコンクリートの接合法（2000年代～2010年代）
スリット入り鋼板を用いた耐震壁（2000年代～2010年代）
NBBとBIE（2010年代）
滑り構造物（2000年代～2010年代）

Experience from 1994 Northridge and 1995 Kobe - Comparison in Seismic Performance of Steel Moment Frames Between the United States and Japan

by

Masayoshi Nakashima

Professor Emeritus, Kyoto University
President, Kobori Research Complex
Counselor, Kajima Corporation

Serious Damage Disclosed in Urban Regions

1994 Northridge
January 17, 1994

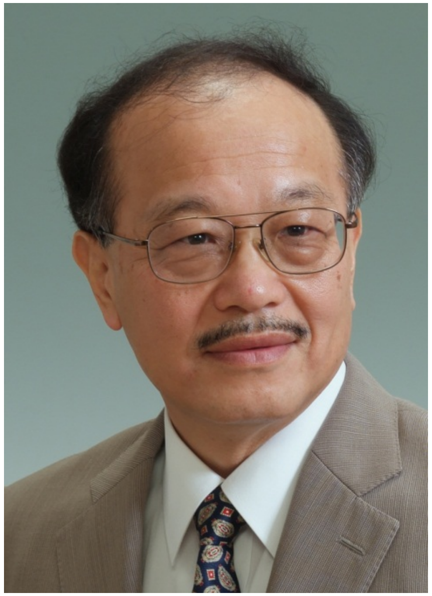
1995 Kobe
January 17, 2995

Highways

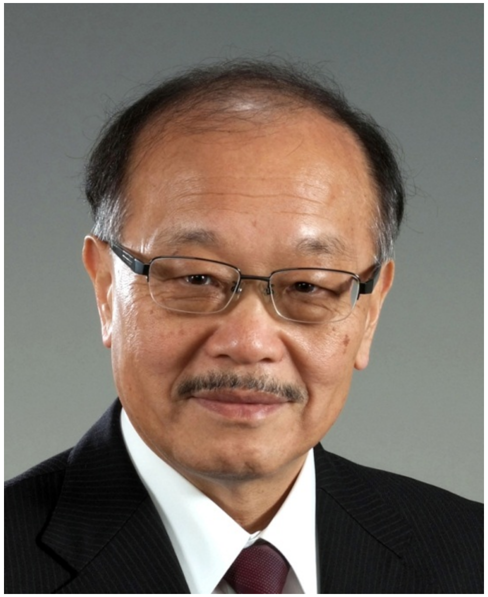
Buildings

“Twenty years” is long!

Masayoshi in 1990s



Masayoshi in 2000s



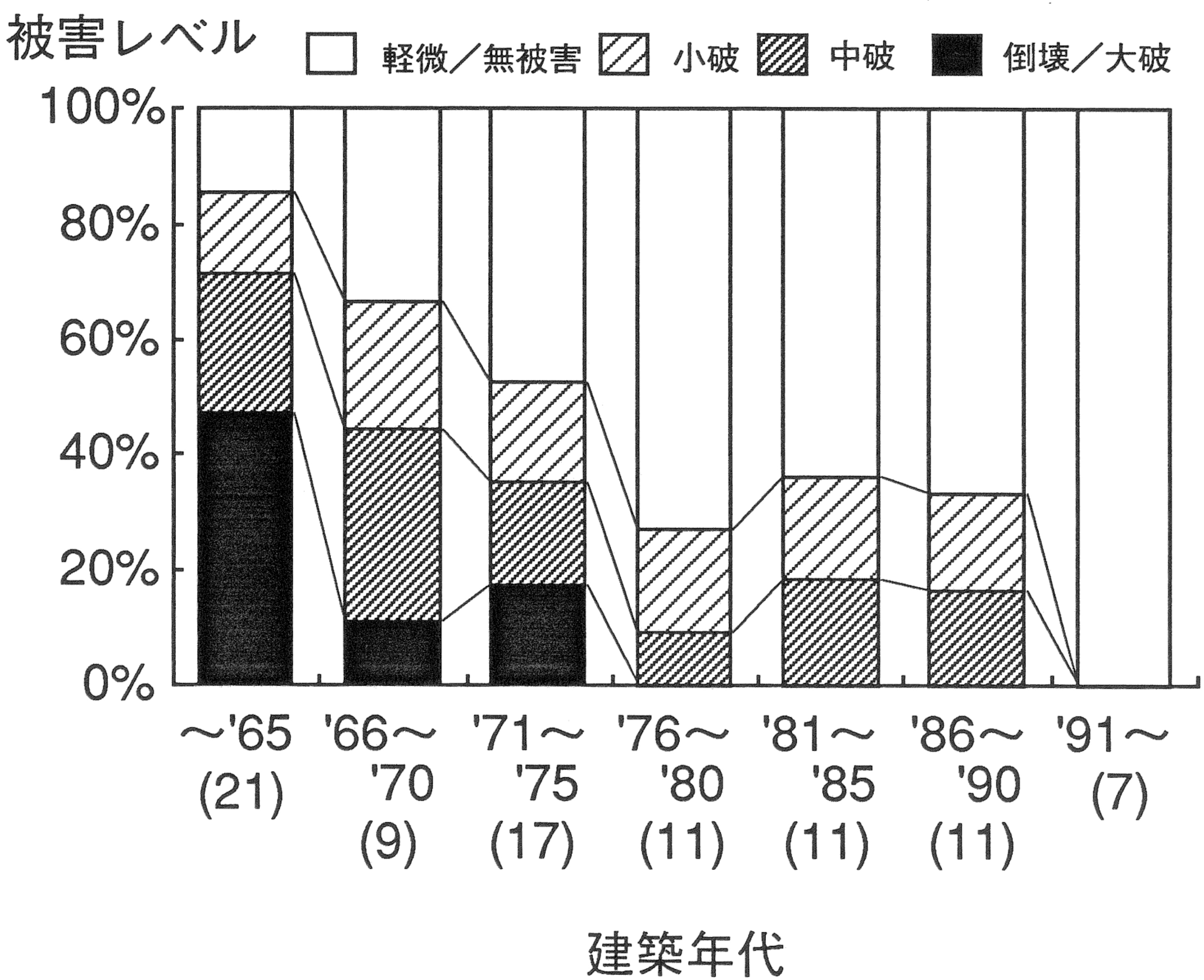
Masayoshi in 2010s

How was earthquake reconnaissance twenty years ago??

Facsimiles	→	E-mail
Analog Cameras	→	Digital Cameras
Land Phones	→	Cellphones
Printed Reports	→	Internet, PDF, etc.

Structural Damage in 1995 Kobe Earthquake

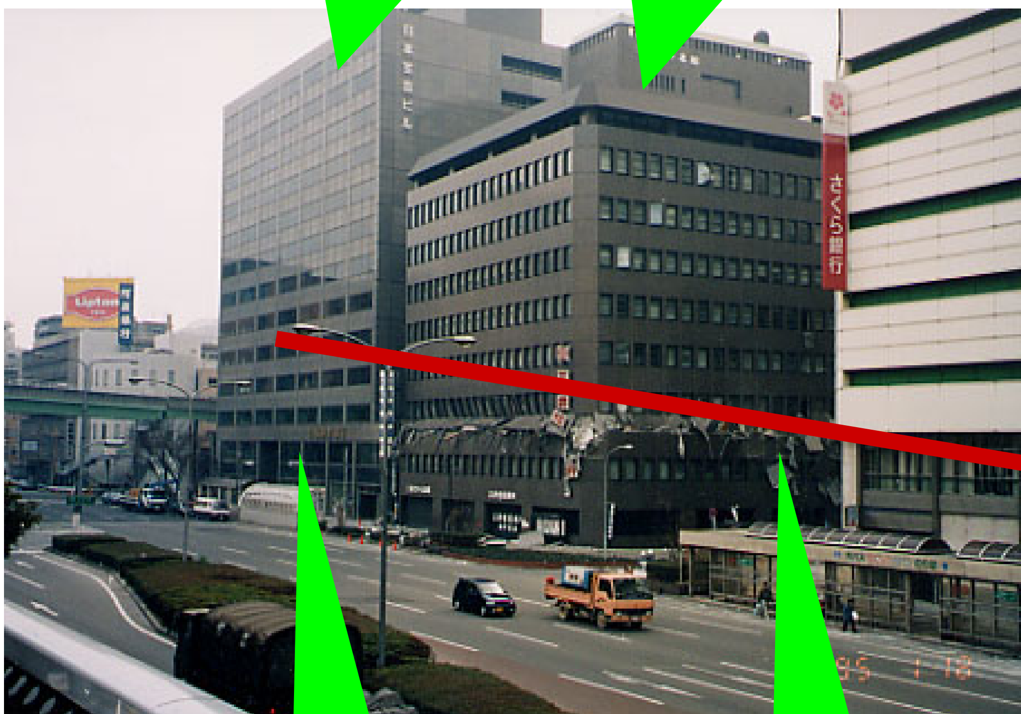
Notable Difference in Damage Level: Correlation with Building Age



Clear Contrast of Damage to RC Buildings

Standing Firm

3rd story failure



After 1981

Before 1981

Wall damage
- Acceptable -

“Learning from Earthquakes”

Earthquake engineering has a long history of “learning from actual earthquakes and earthquake damages.” That is, we first understand problems by actual damage; then develop engineering to patch them.

1964 Niigata

Liquefaction

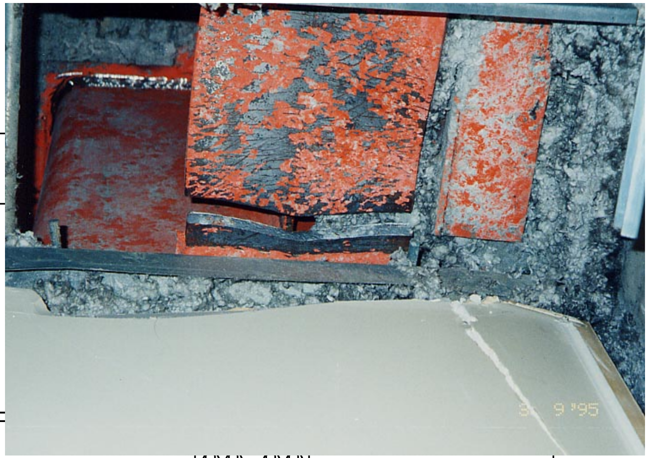
1968 Tokachi-oki

RC Shear Failure

1995 Kobe

Seismic Retrofit

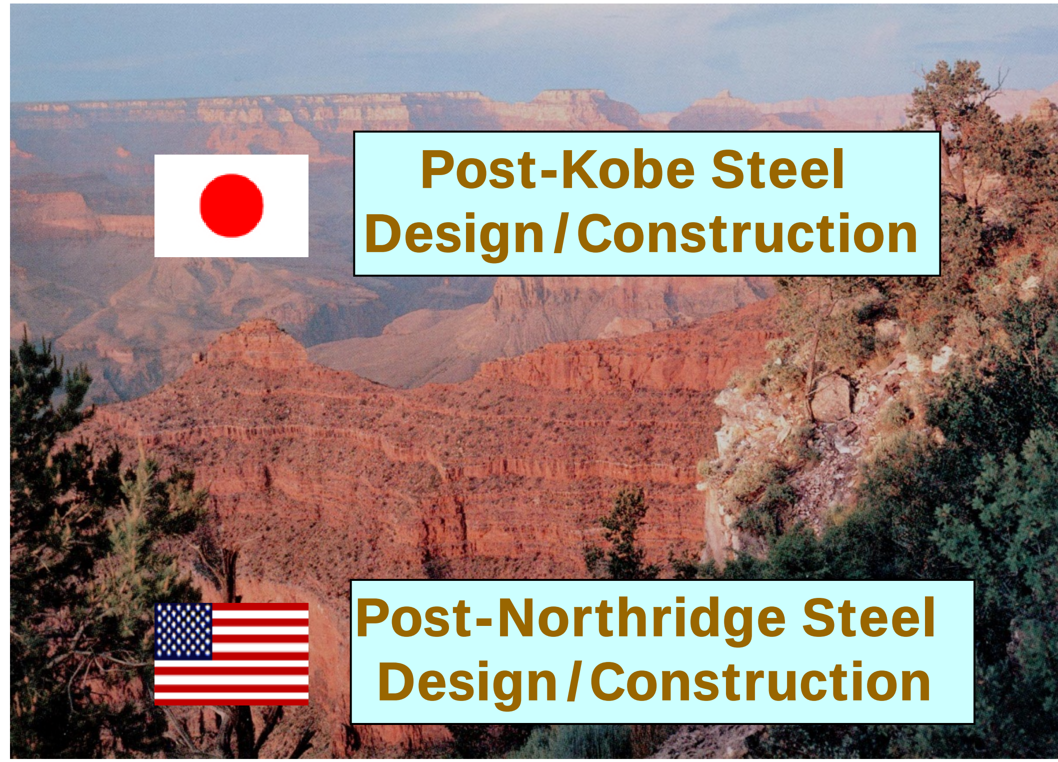
Exception -- Damage to Newer Construction Fractures of Welded Beam-to-Column Connections – damage similar in 1994 Northridge



Steel Damage and Post-Earthquake Actions in Northridge/Kobe

Similarities

* Damage to steel buildings
* Near-fault motions larger than those considered in design
* Damage to modern buildings
* Weakness of welded beam-to-column connections



Comparison in U.S. and Japanese Seismic Provisions

Publications:

Nakashima, M., Roeder, C. W., and Maruoka, Y. (2000). "Steel Moment Frames for Earthquakes in the United States and Japan," Journal of Structural Engineering, ASCE, 126(8), pp.861-868.

Conclusions:

Steel moment frames in US and Japan are similar in the actual strength.

Summary Table

Action (1)	Provisions of 1997 UBC (2)	Provisions of 1981 BCJ (3)
1. Design base shear	Smaller of $V = (C_v I/RT)W$ and $V = (2.5C_a I/R)W$ but not less than $V = 0.11C_a IW$ or not less than $V = (0.8ZN_v I/R)W$ in Seismic Zone 4	Level I Design: $V = C_0 ZR_t W$; Level II Design: $V = D_s C_0 ZR_t W$; where $C_0 = 0.2$ for Level I and $C_0 = 1.0$ for Level II
2. Ground accelerations	Acceleration is $0.4g$ for seismically active regions but is multiplied by soil-site factor to obtain C_a and C_v	Included within Z factor, but maximum ground acceleration is approximately $0.4g$ over most of Japan
3. Site and soil effects	Tabular data varies maximum design ground acceleration by ratio between 0.8 and 3.5 for long period and between 0.8 and 2.4 for short period structures	$R_t = 1$ if $T < T_c$; $R_t = 1 - 0.2[(T/T_c) - 1]^2$ if $T_c \le T < 2T_c$; and $R_t = (1.6T_c/T)$ if $T \ge 2T_c$; where $T_g < 0.2$ s is firm (Type I); $0.2 \text{ s} < T_g \le 0.75$ s is soft (Type II); $T_g > 0.75$ s is very soft (Type III); and $T_c = 0.4$, 0.6, and 0.8 s for Types I, II, and III, respectively
4. Spectra	2.5 for short periods and inversely proportional to T at long periods	2.5 for short periods and inversely proportional to T at long periods
5. Period	Method A: $T = 0.0853h^{3/4}$ (in meters)	$T = 0.03h$ (in meters)
6. Ductility	$R = 8.5$ for special moment-resisting frames	$D_s = 0.25$ for FA ductility condition
7. Vertical distribution of seismic force	Added force at top story is $F_t = 0.07VT$ if $T > 0.7$ s and basic force at all floor levels is $F_i = [(V - F_t)w_i x_i / \Sigma_{j=1}^{n} w_j x_j]$	Story shear in ith story is $V_i = ZR_t A_i C_0 \Sigma_{j=i}^{n} w_j$, where $A_i = 1 + (1/\sqrt{\alpha_i} - \alpha_i)[2T/(1 + 3T)]$ and $\alpha_i = (\Sigma_{j=i}^{n} w_j/W)$
8. Horizontal distribution	Distributed in proportion to floor mass distribution plus minimum torsional eccentricity	Considered as distributed in proportion to floor mass distribution but no minimum torison
9. Drift limits	At factored reduced loads: $(0.7R\Delta_s/h_s) \le 0.025$ if $T \le 0.7$ s and $(0.7R\Delta_s/h_s) \le 0.02$ if $T > 0.7$ s	For Level I loading: $(\Delta_s/h_s) \le 1/200$
10. Detail requirements for steel moment frames	For special moment-resisting frames: bracing for lateral torsional buckling—$L_b \le (2{,}500r_y/F_y)$; slenderness for flange buckling—$(b_f/2t_f) \le (52/\sqrt{F_y})$; slenderness requirements for web buckling—$(d/t_w) \le (520/\sqrt{F_y})[1 - 1.54(P_u/\phi P_y)]$ for $(P_u/\phi P_y) \le 0.125$ and $(d/t_w) \le (191/\sqrt{F_y})[2.33 - (P_u/\phi P_y)]$ for $(P_u/\phi P_y) > 0.125$, except that $(d/t_w) > (253/\sqrt{F_y})$	For FA ductility condition: for square tubes $b/t \le 27$ for SM490 steel; slenderness for flange buckling of H-beams—$(b_f/2t_f) \le 7.5$ for SM490 steel; slenderness for web buckling of H-beams—$(d/t_w) \le 51$ for SM490 steel; bracing for lateral torsional buckling—$L_b \le 130r_y$ for SM490 steel with uniform bracing over span length
11. Panel zone shear	Shear caused by $0.8R_y \Sigma M_{p\,\text{beams}}$ must be $\le V_p = 0.6F_{yc}d_c t_{wc}[1 + (3b_c t_{cf}^3/d_b d_c t)]$	Wide flanges, shear caused by $0.75 \Sigma M_{y\,\text{beams}}$ must be $\le V_y = 0.56F_{yc}d_c t_{wc}$ and V_y increased by 16/9 for tubes
12. Other issues	1. I—increases forces up to 1.5 for critical structures 2. Load factor design, but member forces determined by linear elastic or approximate analysis	1. Level I = structure remains elastic 2. Level II = structure does not collapse 3. Peer review required for buildings over 45 m

Differences in Damage, Design, and Construction

Beam Plastic Rotation Capacity


Fracture after plastification / local buckling


Fracture with almost no plastification

Columns and Connections


Box columns, Through diaphragm connections


Wide flange columns, Web-bolted Flange-welded connections

Materials


SN steel, Low Yield-Ratio


Dual-purpose steel

Welding


GMAW, Shop-welding


FCAW, Field-welding

Structural System

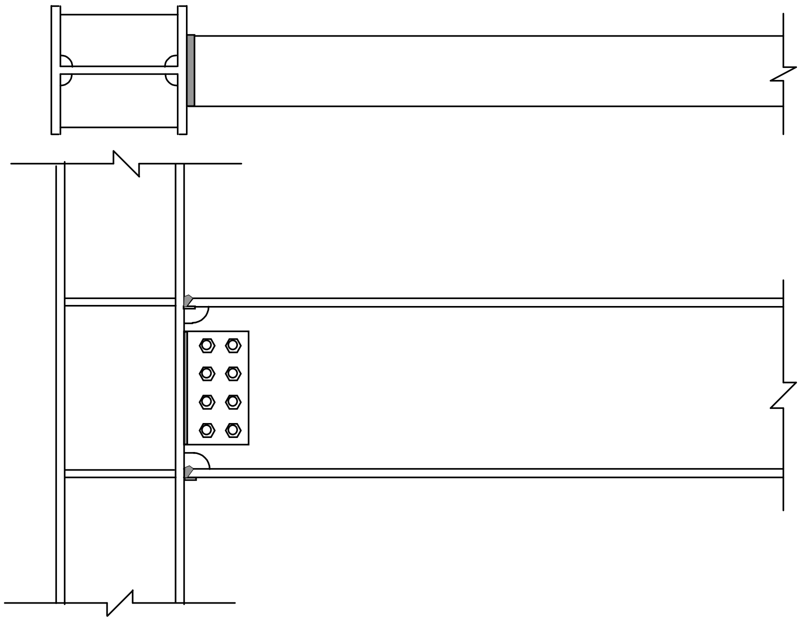

All rigid connection

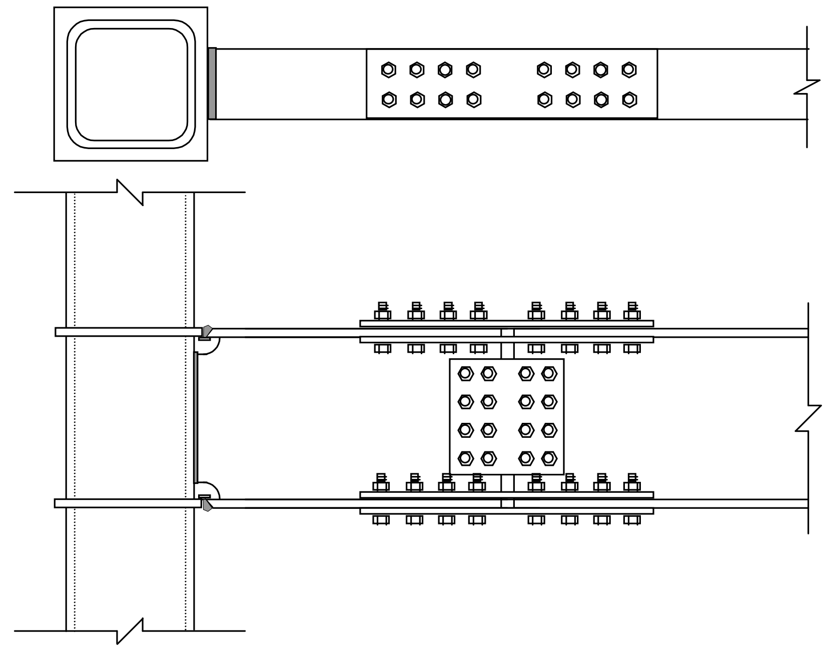

Rigid connection at selected locations

Differences in Beam Plastic Rotation Capacity

Fracture after plastification / local buckling	Fracture with almost no plastification

Columns and Beam-to-Column Connections

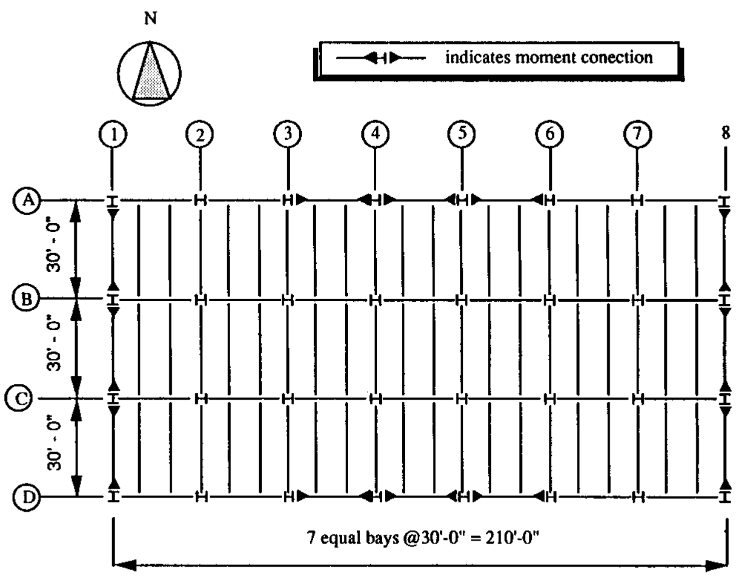


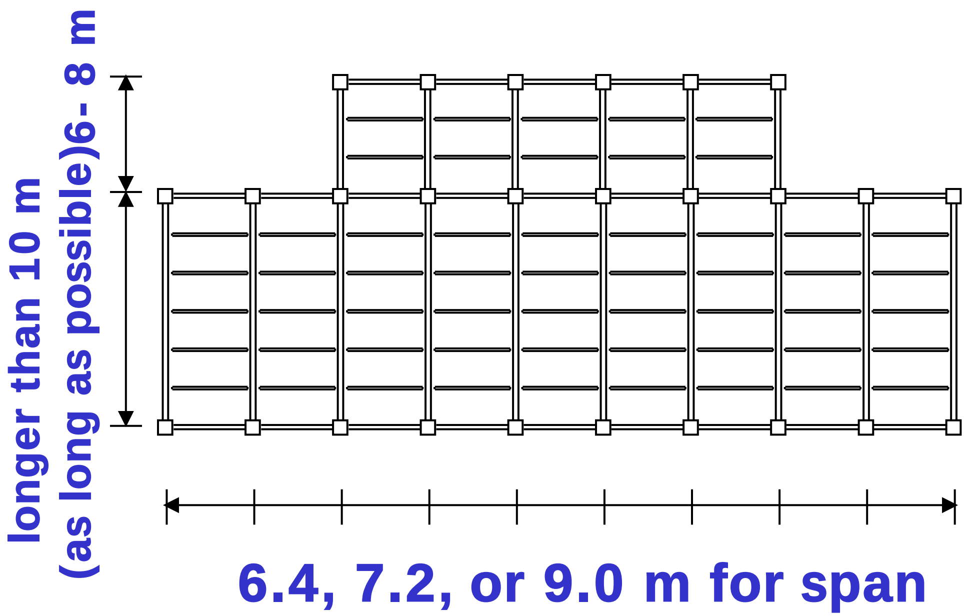


Wide flange columns, Web-bolted Flange-welded connections

Box columns, Through diaphragm connections

Type of Structural System Used in Japan and U.S.





US-System
(selected rigid connection)

Japanese-System
(all rigid connection)

Differences in Post-Earthquake Actions

Tougher Steel

SN steel, Yield-Ratio<0.8

A992 steel, Yield-Ratio<0.85

Acceptance faster in Japan

Welding

More stringent bead placement

Use of tougher electrodes

More explicit changes in U.S.

Connections

Modified weld access holes

Cover plates, haunches, RBS

Difference Significant between Japan and U.S.

Structural System

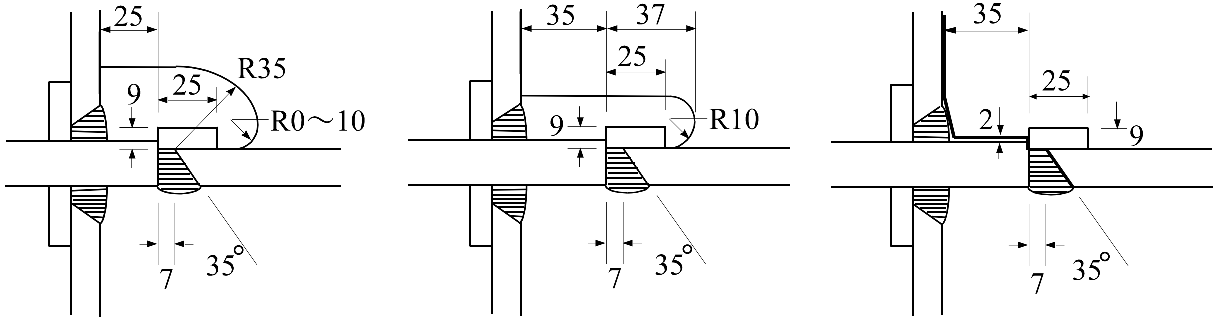
Use of box columns,
All rigid connections

Use of wide flange columns
Rigid Connections in selected locations,
Redundancy factor

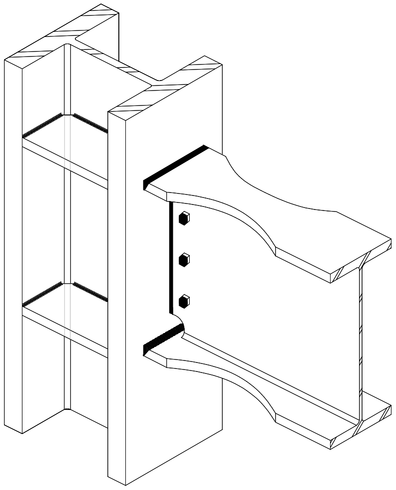
No Significant Change in both Japan and U.S.

Differences in Connection Details

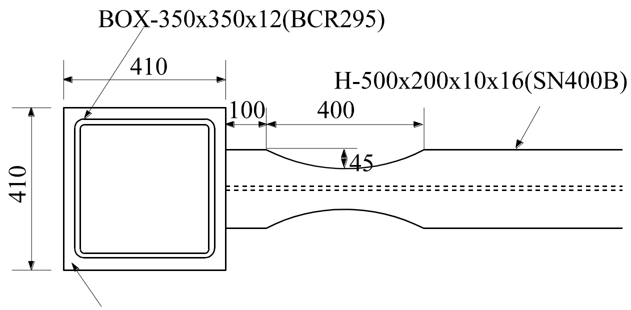
Modified weld access holes



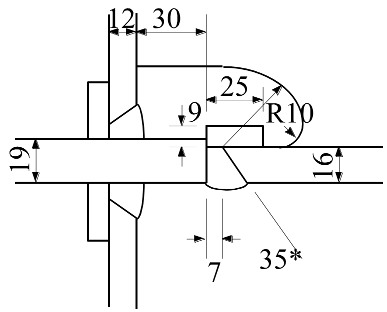
Cover plates, haunches, RBS



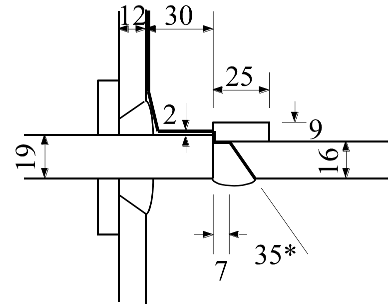
Seismic Performance of Beam-to-Column Connection in Japan and U.S. (JV with Univ. of Texas at Austin)



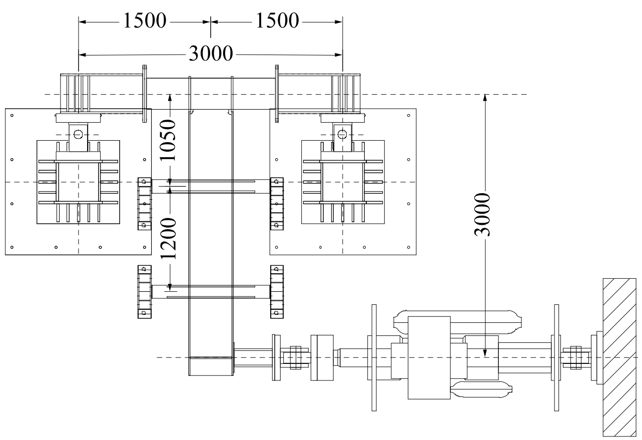
RBS Connection



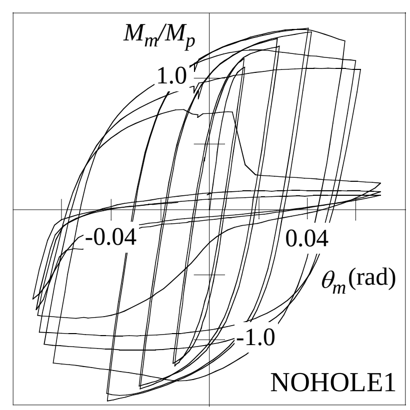
US Standard Hole



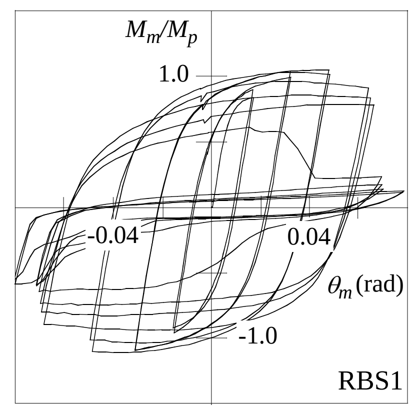
Japan's No-Hole



Test Setup



Japan No-Hole Detail



US RBS Detail

Publication: Suita, K., Tamura, T., Morita, S., Nakashima, M., and Engelhardt, M. D., "Plastic Rotation Capacity of Steel Beam-to-Column Connections Using a Reduced Beam Section and No Weld Access Hole Design," Journal of Structural and Construction Engineering, Architectural Institute of Japan, No.526, December 1999, pp.177-184 (in Japanese).

Lessons Learned

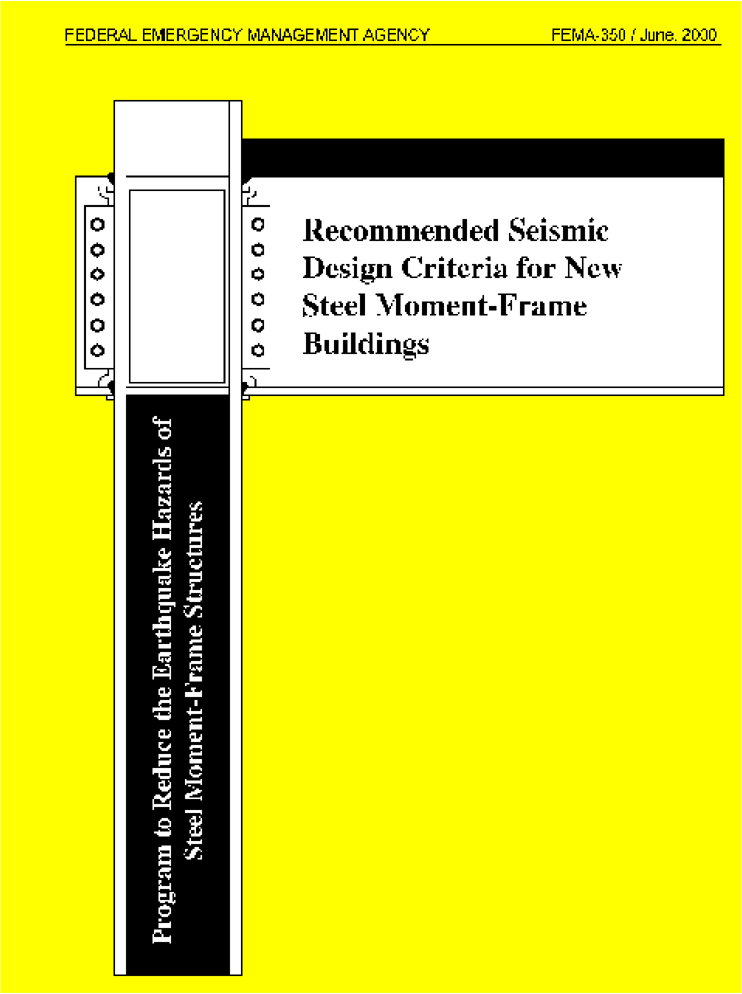
Engineering has multiple solutions -- Then, which solution is to be adopted?

"Construction" (relative to "Design") appears to have more direct impact on daily business.

"Details" (relative to "Fundamentals)" are said the heart of structural engineering (in particular in the Japanese construction society).

Solutions that can be accepted (as most feasible) by construction practice are the ones to adopt.

Post-Earthquake Design Consideration



FEMA-355E

APPENDIX C. OVERVIEW OF DAMAGE TO STEEL BUILDING STRUCTURES OBSERVED IN THE 1995 KOBE EARTHQUAKE

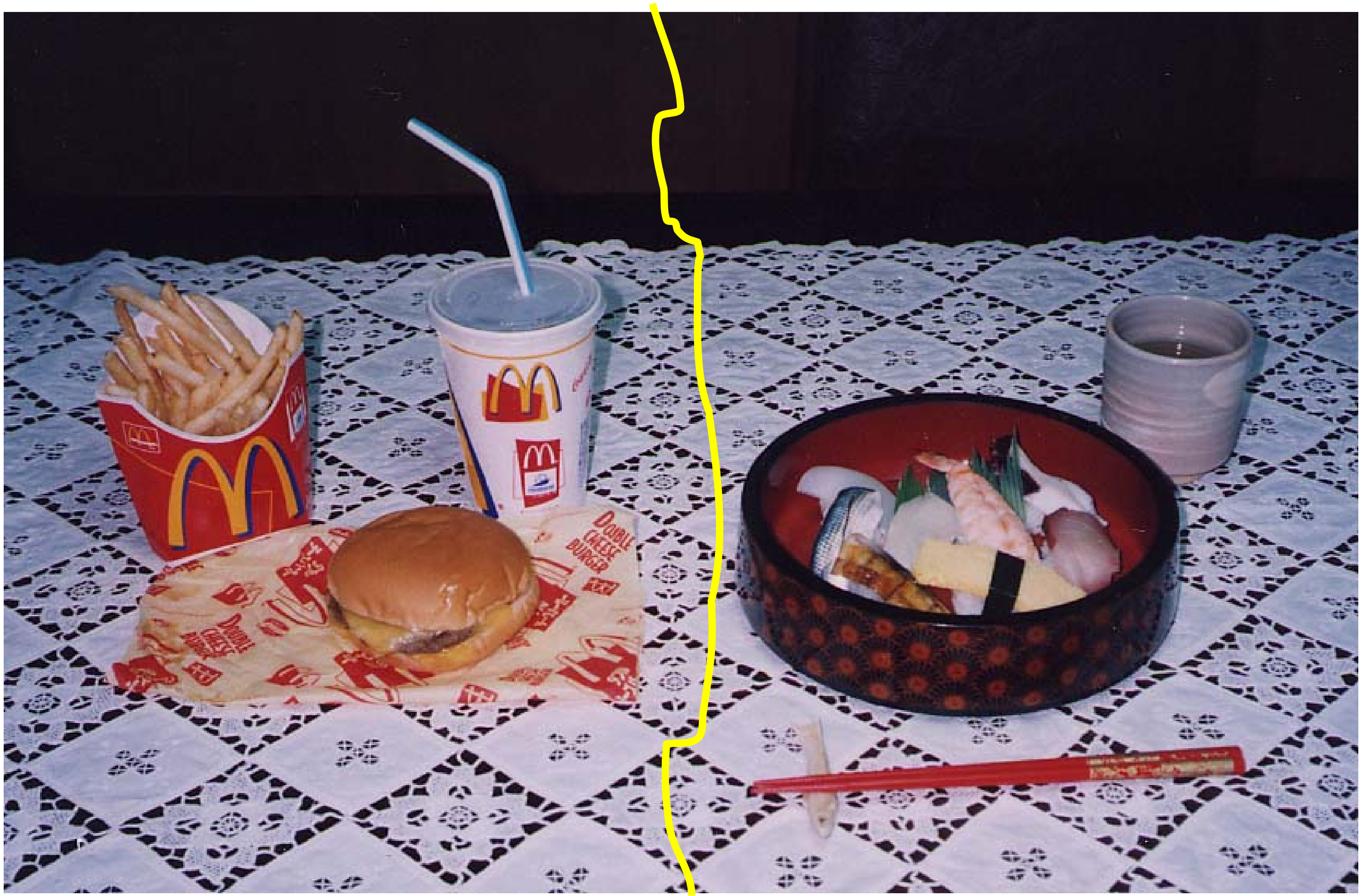
THE 1995 HYOGOKEN-NANBU (KOBE) EARTHQUAKE

Masayoshi Nakashima
DISASTER PREVENTION RESEARCH INSTITUTE, KYOTO UNIVERSITY

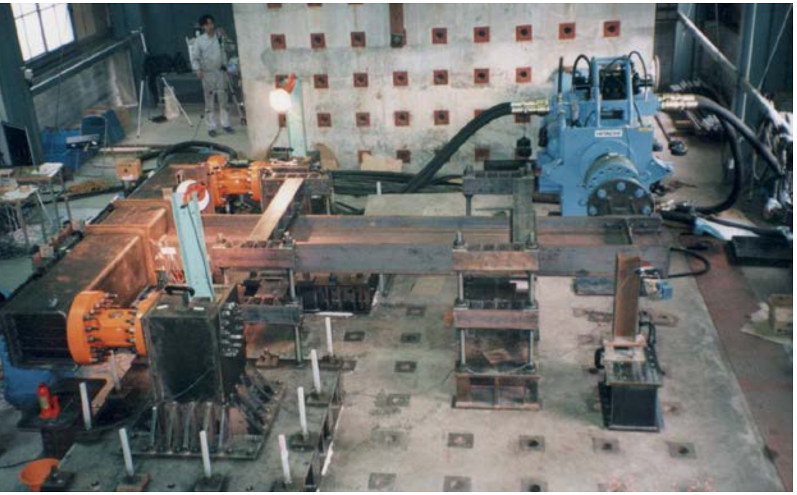
C.1 Summary

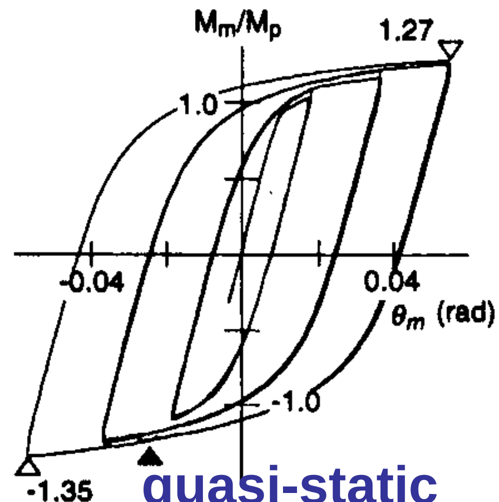
This appendix presents an overview of damage to steel building structures observed following the 1995 Hyogoken-Nanbu (Kobe) earthquake. Damage statistics are presented with respect to the number of stories, type of structural framing, location of damaged elements and severity of damage. Standard practices exercised in Japan before the earthquake and causes of damage discussed immediately after the earthquake are introduced in terms of materials, welding, beam-to-column connection details and seismic design forces. Efforts are made to compare these with corresponding U.S. practices. A partial summary of post-Kobe research activities in Japan on steel structures is also presented.

Significant Difference in Construction Culture Between U.S. and Japan

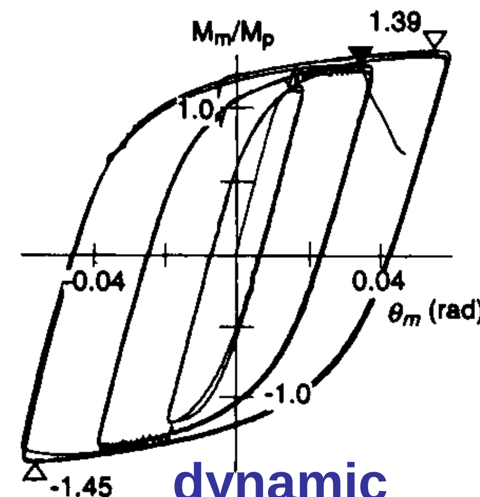


Dynamic Loading Effect on Seismic Performance of Welded Beam-to-Column Connection

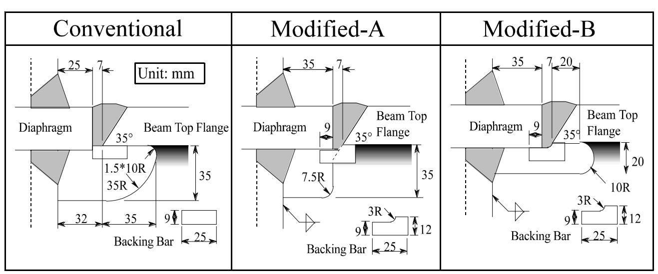




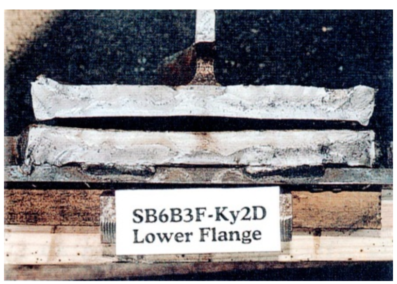
quasi-static



dynamic



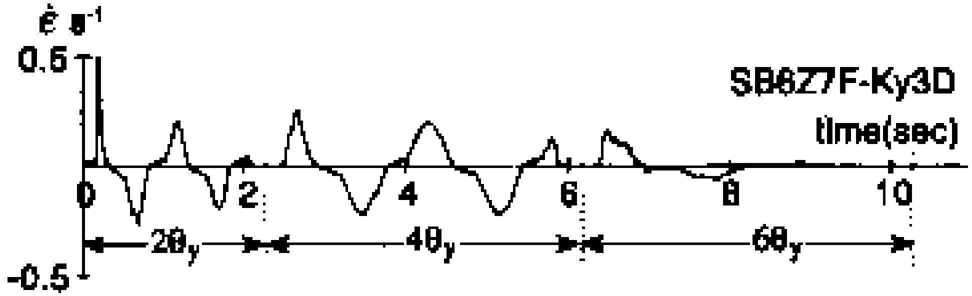
Weld Access Hole Details



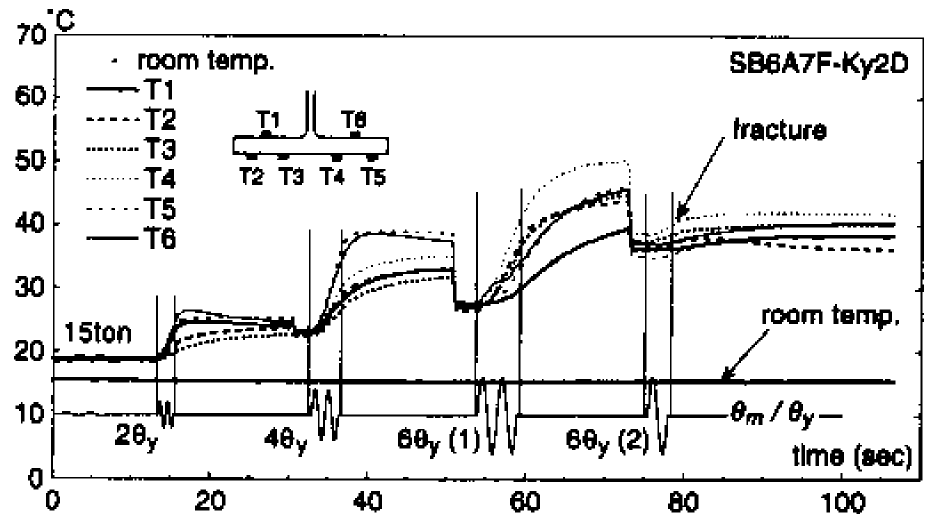
Fracture Surface: Brittle (left); Ductile (right)

Dynamic Loading Effect on Seismic Performance of Welded Beam-to-Column Connection (continued)

Strain Rate History

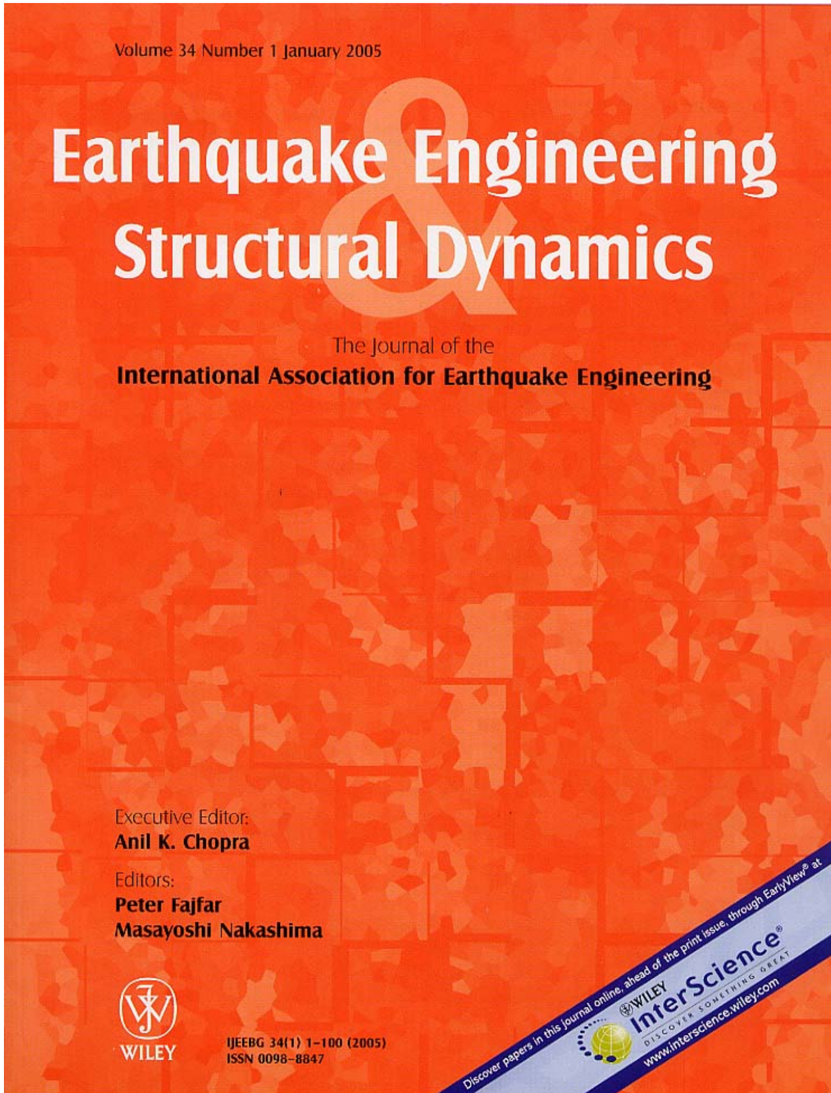


Temperature Change



Publication: Nakashima, M., et al., "Tests of Welded Beam-Column Subassemblies I: Global Behavior," Journal of Structural Engineering, ASCE, Vol.124, No.11, 1998, pp.1236-1244.

Anil Chopra -- The Editor of Earthquake Engineering and Structural Dynamics (EESD)



History of EESD

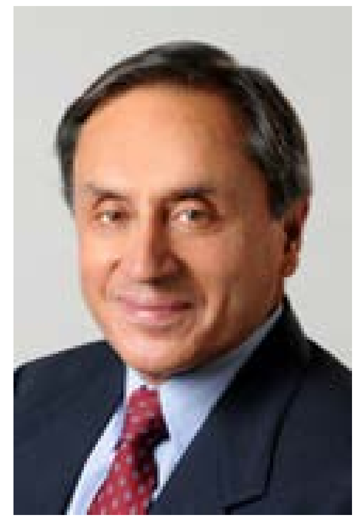
1972 1982 1992 2002 2012 2017

1972 ⟷ 1988 ⟷ 1996 ⟵

16 years 8 years >21 years

R. Clough

J. Warburton



A. Chopra

G. Warburton (1972 - 1994)

A. Chopra (1988 - 1996)

T. Chaughy (1996 - 2004)

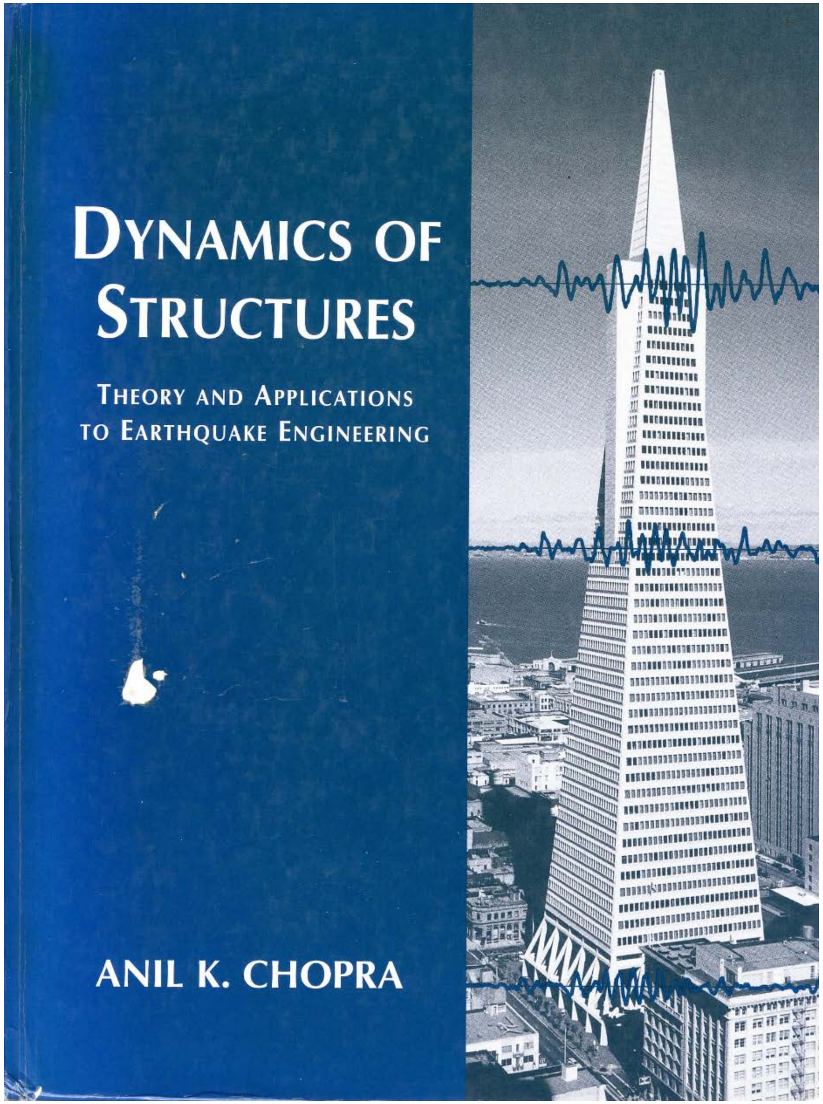
H. Aoyama (1996 - 2003)

P. Fajfar (2003 - 2016)

M. Nakashima (2005 - date)

M. Fardis (2015 - date)

My Copy of "Dynamics of Structures" by Anil Chopra



Dear Masayoshi

I hope that even an expert like you will find in this book new insights into dynamics of structures.

Anil K. Chopra
Oct 31, 1995

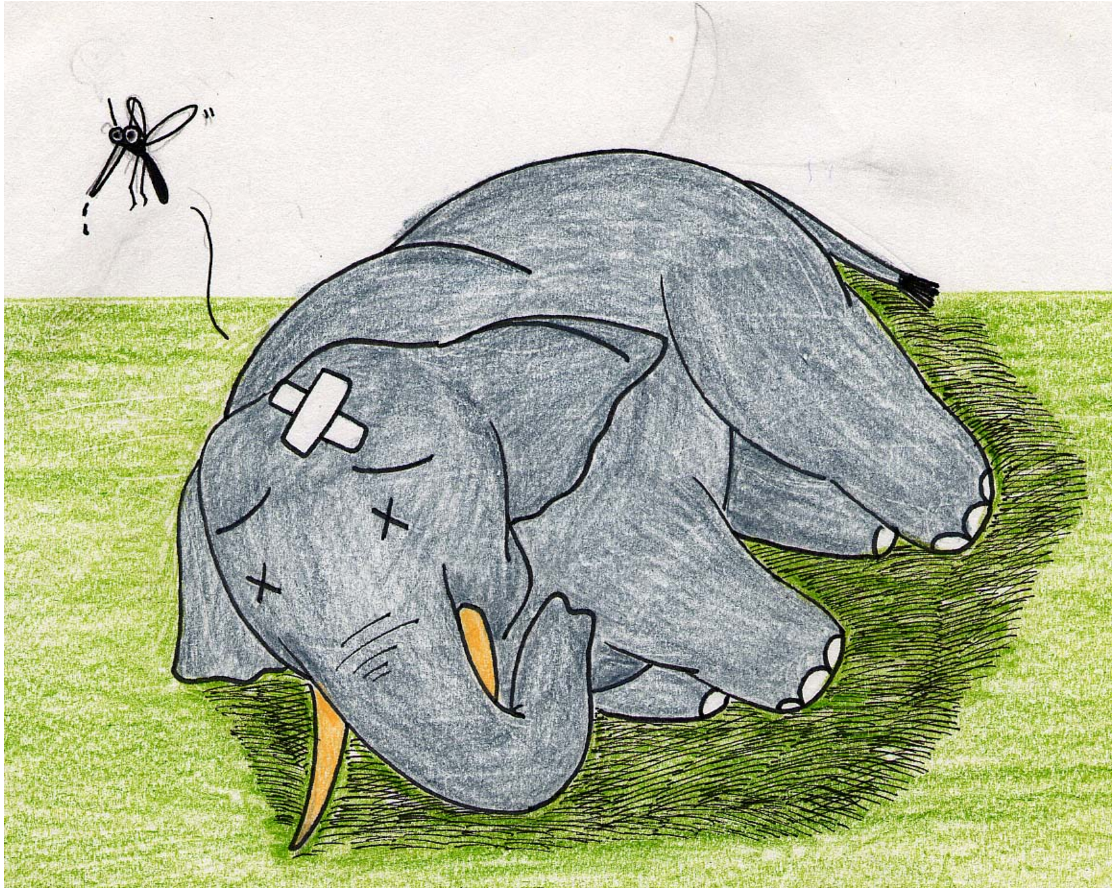
Closure

I find myself extremely lucky to have become acquainted with Professor Chopra through the work on editorship in Earthquake Engineering and Structural Dynamics (EESD). Indeed, I have learned very many from him particularly on "quality of research".

I wish the best of long-lasting health of Professor Chopra and his continuing support and encouragement to the earthquake engineering communities throughout the world.

Shall an elephant (structural frame) collapse by a bite of a mosquito (tiny weld defect)?

WRONG – We should develop robust connections!



My Daughter's Family

Sincere Appreciation to Professor Chopra for His Leadership of EESD

I had an honor to become acquainted with Professor Anil Chopra in the summer of 1994 when I stayed in UC Berkeley during my sabbatical.

It was the restaurant of Berkeley's Faculty Club when I met him in person for the first time and my long-term friendship with him was initiated.

Later, he invited me to the Advisory Editorial Board of EESD and further to the editorship of EESD. Since that time, I regularly interact and meet with Professor Chopra, and it has lasted more than two decades.

Sincere Appreciation to Professor Chopra for His Leadership of EESD

I learnt very many things from Professor Chopra, in particular those related to how to manage the quality of academic journals.

The journal editor is destined to encounter cases in which disagreement occurs between the authors and reviewers. In early days of my editorship, I was troubled with a few of such cases and naturally consulted with Professor Chopra.

His advice was always clear and solid, and the most significant among what I learnt from his advice was "no trembling once we decide".

Sincere Appreciation to Professor Chopra for His Leadership of EESD

Dispute between authors and reviewers is commonly not black-and-white, with their respective contentions making some sense, but the journal editor has to make decision. Changing the decision in mid-way or in future similar cases would bring skepticism to both the authors and reviewers, and if we repeat changing the decision, we will eventually lose our credential, which in turn will be the demise of the journal.

Thanks to the strong leadership of Professor Chopra, EESD has maintained and promoted its reputation for the past two decades as the highest-quality journal in the disciplines of earthquake engineering and structural dynamics.

Sincere Appreciation to Professor Chopra for His Leadership of EESD

I find myself extremely lucky to take part in the editorship of this prestigious journal that has been nurtured by Professor Chopra.

I wish the best of long-lasting health of Professor Chopra and his continuing support and encouragement to the earthquake engineering communities throughout the world.