Proceedings of

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL

Hong Kong
18-21 December 1996

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1. Announcement

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
"Next Generation of Intelligent Structures"

18-21 December 1996

LOCATION: Hong Kong University of Science and Technology (HKUST)

SPONSOR: International Association of Structural Control (IASC) in conjunction with the Japan Panel on Structural Response Control and US Panel on Structural Control Research**.**

HOST: The local host was the Research Centre at HKUST which is a branch of the university charged with developing applied research programs that are relevant to Hong Kong's economic and social development.

OBJECTIVE:
The purpose of this Workshop was to bring together engineers and others interested in the general field of response control and monitoring of buildings, bridges and other civil infrastructure systems, in order to facilitate research, development and applications of these technologies to improve safety, serviceability and economy of these structures when subjected to environmental loads. To achieve this objective, the Workshop program was structured so that participants can:
(1) share new information and ideas relating to these technologies,
(2) work together to promote international cooperation for advancing these technologies by sharing knowledge, resources and test facilities.

PAPERS: Approximately 60 invited and contributed papers were presented on applications and research in response control and monitoring of buildings, bridges and other infrastructure systems. Contributed papers were selected on the basis of abstracts submitted in response to an earlier Call for Papers.

PUBLICATIONS: accepted papers and invited papers will be published in an electronic Workshop. Proceedings and will be made available via Internet. Printed copies were also distributed at the Workshop.

WORKING GROUPS: Participants were organized into six working groups:

- Building Control;
- Bridge Control;
- Health Monitoring;
- Case Studies of Control;
- Design Philosophy for Control Codes; and
- Future Directions for IASC.

WORKSHOP PROGRAM:

DAY 1 - PLENARY SESSIONS (all day): Current Status of Research Programs in Control, Monitoring and Wind Engineering; Current Status of Implementations in Control and Monitoring; Present and Future for IASC; Reception

DAY 2 - WORKING GROUP SESSIONS (am) and BRIDGE FIELD TRIP (pm)

DAY 3 - PARALLEL SESSIONS (am): Modeling, Monitoring and System ID; Control Algorithms and Systems; Control Devices, Tests and Applications
- PLENARY SESSION (pm): Working Group Reports; General Discussion and Resolutions; Banquet

DAY 4 - LANTAU ISLAND FIELD TRIP (all day)

FIELD TRIPS: Participants had the opportunity on Thursday, 19 December to visit the site of the Tsing Ma suspension bridge which was under construction to provide access to the new Chek Lap Kok Airport on Lantau Island.

PARTICIPATION: Participation in the Workshop was limited because of restricted capacity for meeting facilities and field trips. First priority was given to the speakers and working group chairs and reporters.

REGISTRATION: The Workshop registration fee was US$300 or HK$2340 which included lunches, reception, banquet, daily transport between Tsim Sha Tsui, Kowloon, and the HKUST campus, and field trips.

STEERING COMMITTEE:

J. Chen, HKUST, Hong Kong (Chair); J. Beck, Caltech, USA
F. Casciati, Univ. of Pavia, Italy; G. Hirsch, RWTH Aachen, Germany
H. Iemura, Kyoto Univ., Japan;Y. Inoue, Osaka Univ., Japan

S. Masri, Univ. of Southern Cal., USA;A. Nishitani, Waseda Univ., Japan
T. Soong, S.U.N.Y. Buffalo, USA; L. Xie, Harbin Inst. of Eng. Mech., PRC
C. Yeh, Nat. Cent. for Res. on Earthq. Eng., Taiwan

2. Program

FINAL PROGRAM FOR
SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
"Next Generation of Intelligent Structures "
Hong Kong, 18-21 December 1996

DAY 1: Wednesday, 18 December 1996

07:45- Bus departs from Hotels to HKUST

09:00-09:30 Registration outside Lecture Theatre E, Academic Concourse

PLENARY SESSION I [Lecture Theatre E]:

09:30-10:00 Welcome

* President of HKUST and HKUST Video (C.W. Woo)
* President of IASC (T. Kobori)
* Logistics (J.C. Chen)

10:00-10:40 Current Status of Research & Implementations (Part I)
Chair: J.C. Chen

* Control Research in Japan, Y. Inoue
* Control Research in USA, M.P. Singh

10:40-10:50 Group Photo Taking
(Open Area Outside Lecture Theatre A)

10:50-11:10 Break

11:10-12:10 Current Status of Research & Implementations (Part II)
Chair: J.C. Chen

* Control Research in Europe, F. Casciati

* Wind Engineering Research in Japan, Y. Tamura
* Wind Engineering Research in USA, A. Kareem

12:10-13:10 Lunch in G/F Chinese Restaurant

PLENARY SESSION II [Lecture Theatre E]:

13:10-15:10 Current Status of Research & Implementations (Part III)
Chair: S.F. Masri

* Remarks on Structural Control, S.C. Liu
* Monitoring Implementations, R. Nigbor
* Building Control in Japan, A. Nishitani
* Bridge Control in Japan, Y. Fujino
* Practical Issues in Control, M. Sakamoto

15:10-15:40 Break

15:40-16:00 * The Present and Future for IASC, T. Kobori

WORKING GROUP SESSIONS I [Classrooms near Lecture Theatre E]:

16:00-18:00 Working Group Planning Meetings

* Building Control (LTE)
[Co-Ch: J. Yang, K.Seto, C.S. Yeh, B.F. Spencer(R)]

* Bridge Control (Rm 1504)
[Co-Ch: A. Kareem, T. Miyata, L.A. Bergman(R)]

* Health Monitoring (Rm 1401)
[Co-Ch: R. Nigbor, S. Yamamoto, J.C. Chen, J.L. Beck(R)]

* Case Studies of Control (Rm 1402)
[Co-Ch: M. Riley, H. Iemura, W.H. Robinson, H. A. Smith(R)]

* Design Philosophy for Control Codes (Rm 1403)
[Co-Ch: M. Sultan, Y. Kitagawa, F. Casciati, W.D. Iwan(R)]

* Future Directions for IASC (Rm 1505)
[Co-Ch: G.W. Housner, T. Kobori, S.F. Masri(R)]

18:00-19:30 Reception outside Lecture Theatre E

19:30- Bus departs from HKUST Piazza to Hotels

DAY 2: Thursday, 19 December 1996

07:45- Bus departs from Hotels to HKUST

WORKING GROUP SESSIONS II [Classrooms, 3/F, Lifts 17 & 18]:

09:00-10:30 Working Group Meetings (Part I)

* Building Control (Rm 3315)
[Co-Ch: J. Yang, K.Seto, C.S. Yeh, B.F. Spencer(R)]

* Bridge Control (Rm 3311)
[Co-Ch: A. Kareem, T. Miyata, L.A. Bergman(R)]

* Health Monitoring (Rm 3308)
[Co-Ch: R. Nigbor, S. Yamamoto, J.C. Chen, J.L. Beck(R)]

* Case Studies of Control (Rm 3302)
[Co-Ch: M. Riley, H. Iemura, W.H. Robinson, H. A. Smith(R)]

* Design Philosophy for Control Codes (Rm 3301)
[Co-Ch: M. Sultan, Y. Kitagawa, F. Casciati, W.D. Iwan(R)]

* Future Directions for IASC (Rm 3301A)
[Co-Ch: G.W. Housner, T. Kobori, S.F. Masri(R)]

10:30-11:00 Break

11:00-12:30 Working Group Meetings (Part II)

12:30-13:30 Lunch in G/F Chinese Restaurant

FIELD TRIP:

13:45- Bus departs HKUST Piazza to Tsing Ma Bridge

14:30-16:30 Site Visit to North Tower

16:30-18:00 Return to HKUST via Tsim Sha Tsui Hotels

DAY 3: Friday, 20 December 1996

07:45- Bus departs from Hotels to HKUST

PARALLEL SESSIONS [Classrooms, 3/F, Lifts 17 & 18]:

09:00-10:30 [Each paper has 10 minutes]

Session 1a - Monitoring, Modelling and System ID (Rm 3315), Ch: J.L. Beck

* Distributed health monitoring system for a tall building, A. Mita

* A remote wireless infrastructure health monitoring system for damage assessment, D.J. Pines

* A modular, visual approach to damage monitoring for civil structures, E.G. Straser and A.S. Kiremidjian

* Wind response observation of a slender building with a hybrid mass damper: "Hirobe-Miyake Building", Y. Nakamura, K. Tanaka, M. Nakayama, Y. Sasaki, and T. Fujita

* Monitoring of structural systems by using frequency data, D. Capecchi and F. Vestroni

* Aerospace applications of analytical model improvement techniques with potential benefits to earthquake engineering, A. Berman

* Concept of model reduction for structural control, A. Nishitani, N. Yamada, Y. Nitta and S. Yamada

* A parametric approach to nonlinear structural identification using neural networks, K. Nikzad, K. Saberi Haghighi and M. Ghafory-Ashtiany

Session 1b - Control Algorithms and Systems (Rm 3311), Ch: L.A. Bergman

* Control laws for semi-active tuned liquid column damper with variable orifice openings, M. Abe, S. Kimura and Y. Fujino

* Seismic response control using multiple MR dampers, S.J. Dyke and B.F. Spencer, Jr.

* Application of active and semi-active devices for the control of building vibrations, P.B. Shing, B. Rose, M.E. Dixon, S.D. Kang and N. Kermiche

* New developments in active interaction control, W.D. Iwan and L.J. Wang

* Optimum seismic structural response control using hysteretic damper, K. Asano and H. Nakagawa

* Structural vibration control by passive dampers considering soil-structure interaction, H. Gao, B. Samali and K.C.S. Kwok

* A study on vibration reduction of multi-TLDSs to high-rise structures, H.N. Li, B.M. Wang and Y.L. Sun

* Robust active control of base isolated structures including actuator=

dynamics, N. Luo, J. Rodellar and M. De La Sen

* Active vibration control system using base isolation and dynamic vibration absorber, K. Yoshida and T. Watanabe

Session 1c - Devices, Tests and Applications (Rm 3308), Ch: H. Iemura

* Exploiting SMA bars in energy dissipators, M. Attanasio, L. Faravelli and A. Marioni

* Experimental and analytical studies of structural control system using shape memory alloy, M. Higashino, S. Aizawa, P.W. Clark, A.S. Whittaker, I.D. Aiken and J.M. Kelly

* Magneto-rheological fluid dampers: Scalability and design issues for application to dynamic hazard mitigation, J.D. Carlson and B.F. Spencer, Jr.

* High force electro-rheological damper designs, H.P. Gavin

* Structural control with controllable fluid dampers: Design and implementation issues, N. Makris and S. McMahon

* Fuzzy controller implementation, F. Casciati and F. Giorgi

* Seismic energy dissipators for performance-based design, K.C. Tsai

* Damping wind and earthquake induced motion: The New Zealand experience, W.H. Robinson and M.D. Monti

10:30-11:00 Break

11:00-12:30 [Each paper has 10 minutes]

Session 2a - Bridge Control (Rm 3315), Ch: T. Miyata

* Structural control in consideration of flutter response in long span bridges, N.N. Dung, T. Miyata and H. Yamada

* Effects of eccentric mass on flutter of long span bridges, K. Wilde, Y. Fujino, and V. Prabis

* Aerodynamic countermeasures to suppress wake galloping in tandem cables of cable-stayed bridges, M. Yoneda and S.I. Miyachi

* Modeling issues associated with vibration control of cable-stayed bridges subjected to multiple support excitation, H.A. Smith and A.G. Schemmann

* Passive control of suspension bridges under multi-mode buffeting vibration, C.C. Chang, M. Gu and K.H. Tang

* Model tests of hybrid control for dynamic response of girder bridge under one-sided moving load, M. Kawatani, Y. Yamada, K. Seiki and Y. Miwa

* Caltrans/FHWA program for the performance testing of seismic isolation and energy dissipation systems, M. Sultan and L.H. Sheng

* Study and application of aseismic rubber bearings for bridges, W.C. Yuan and L.C. Fan

Session 2b - Control Algorithms and Systems (Rm 3311), Ch: W.D. Iwan

* Sliding mode control of gust response of tall buildings with auxiliary mass dampers, R. Adhikari and H. Yamaguchi

* Output-feedback sliding mode control for civil engineering structures, M.P. Singh, E.E. Matheu and C. Beattie

* Neural network based nonlinear structural control methods, J. Ghaboussi and K. Bani-Hani

* Ensemble training of a structural controller for MDOF systems, G.F.Panariello, R. Betti and R.W. Longman

* Structural control using Kalman filter approach, C.H. Loh, P.Y. Lin and Y.S. Chen

* Application of repetitive control to vibration attenuation in civil engineering structures, A.P. Prell, T.C. Tsao and L.A. Bergman

* Time delay compensation with the identification of random ground motion acceleration for closed-loop structural control, K. Qi and L.L. Xie

* A structural control of vibration method of flexible buildings in response to large earthquakes and strong winds, K. Seto and Y. Matsumoto

* Closed-loop modeling and control of civil structures: Robust control approaches, R. Smith

Session 2c - Devices, Tests and Applications (Rm 3308), Ch: B.F.Spencer

* Preliminary design of experimental facilities for dynamic tests on controlled structural specimens, A. Baratta, D. Rinaldis and G. Zuccaro

* Nonlinear active control experiment of a real size frame structure, H. Iemura, A. Igarashi, Y. Inoue M. and Sakamoto

* Seismic response of a full scale structure with added viscoelastic dampers, K.C. Chang, Y.R. Chen and M.L. Lai

* Application of hybrid mass damper with convertible active and passive modes to high-rise building, H. Hora, H. Miyano, T. Omi, Y. Hitomi and T. Fujita

* Vibration control of a ropeway carrier by a dynamic absorber, H. Matsuhisa, O. Nishihara, M. Takemoto, M. Yasuda and K. Sato

* Performance of tuned liquid dampers under large amplitude excitation, D. Reed, H. Yeh, J.K. Yu, and S. Gardarsson

* Modeling of a variable damper and its application, T. Sato, M. Sato, S. Tanaka and K. Toki

12:30-13:30 Lunch in G/F Chinese Restaurant

PLENARY SESSION III [Lecture Theatre E]:

13:30-15:00 Working Group Reports (Part I), Ch: T. Kobori

* Building Control [Reporter: L.A. Bergman]
* Bridge Control [Reporter: B.F. Spencer]
* Health Monitoring [Reporter: J.L. Beck]
* Case Studies of Control [Reporter: H.A. Smith]

15:00-15:30 Break

15:30-16:15 Working Group Reports (Part II), Ch: G. W. Housner

* Design Philosophy for Control Codes [Reporter: W.D. Iwan]
* Future Directions for IASC [Reporter: S.F. Masri]

16:15-17:30 General Discussion and Resolutions

18:00- Bus departs HKUST Piazza to Banquet Venue:=20 Clearwater Bay Golf & Country Club

18:30-21:00 Banquet

21:15- Bus departs to HKUST and Hotels

DAY 4: Saturday, 21 December 1996

FIELD TRIP

07:45-09:00 Travel from HKUST to Central (Campus residents)

07:45 - Bus departs from Visitor Centre

07:55 - Bus departs from Visitor Centre (Extension Wing)

08:30-09:00 Star Ferry to Central (TST, Kowloon residents)

09:30-10:30 Ferry to Lantau Island from Pier 7 in Central

10:30-11:30 Bus from Mui Wo to Po Lin Monastery

11:30 13:00 Visit Monastery and Outdoor Buddha Site

13:00-14:00 Vegetarian Lunch at Monastery

14:00-15:00 Bus to Kun Yam Temple and Visit

15:00-15:30 Bus to Tai O Town and Visit

15:30-16:30 Bus from Tai O to Mui Wo

16:30- Shopping/sight-seeing in Mui Wo. Choose Own Time to Return to Central by Ferry

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Attachment 2 - List of Paper Titles

Notes: papers submitted for the Plenary Session are marked with "***". Other than these marked papers, all other papers are presented during the Parallel Sessions.

LIST OF ACCEPTED PAPER TITLES

Abe, M., Kimura, S. and Fujino, Y., Control laws for semi-active tuned liquid column damper with variable orifice openings

Adhikari, R. and Yamaguchi, H., Sliding mode control of gust response of tall buildings with auxiliary mass dampers

Asano, K. and Nakagawa, H., Optimum seismic structural response control using hysteretic damper

Attanasio, M., Faravelli, L. and Marioni, A., Exploiting SMA bars in energy dissipators

Baratta, A., Rinaldis, D. and Zuccaro, G., Preliminary design of experimental facilities for dynamic tests on controlled structural specimens

Berman, A., Aerospace applications of analytical model improvement techniques with potential benefits to earthquake engineering

Capecchi, D. and Vestroni, F., Monitoring of structural systems by using frequency data

Carlson, J.D. and Spencer, B.F., Jr., Magneto-Rheological fluid dampers: Scalability and design issues for application to dynamic hazard mitigation

*** Casciati, F., Control research in Europe

Casciati, F. and Giorgi, F., Fuzzy controller implementation

Chang, C.C., Gu, M. and Tang, K.H., Passive control of suspension bridges under multi-mode buffeting vibration

Chang, K.C., Chen, Y.R. and Lai, M.L., Seismic response of a full scale structure with added viscoelastic dampers

Dung, N.N., Miyata, T., and Yamada, H., Structural control in consideration of flutter response in long span bridges

Dyke, S.J. and Spencer, B.F., Jr., Seismic response control using multiple MR dampers

Gao, H., Samali, B. and Kwok, K.C.S., Structural vibration control by passive dampers considering soil-structure interaction

Gavin, H.P., High force electrorheological damper designs

Ghaboussi, J. and Bani-Hani, K., Neural network based nonlinear structural control methods

Higashino, M., Aizawa, S., Clark, P.W., Whittaker, A.S., Aiken, I.D. and Kelly, J.M., Experimental and analytical studies of structural control system using shape memory alloy

Hora, H., Miyano, H., Omi, T., Hitomi, Y. and Fujita, T., Application of hybrid mass damper with convertible active and passive modes to high-rise building

Iemura, H., Igarashi, A., Inoue, Y. and Sakamoto, M., Nonlinear active control experiment of a real size frame structure

Iwan, W.D. and Wang, L.J., New developments in active interaction control

Kawatani, M., Yamada, Y., Seiki, K. and Miwa, Y., Model tests of hybrid control for dynamic response of girder bridge under one-sided moving load

Li, H.N., Wang, B.M. and Sun, Y.L., A study on vibration reduction of multi- TLDSs to high-rise structures

Loh, C.H., Lin, P.Y. and Chen, Y.S. , Structural control using Kalman filter approach

Luo, N., Rodellar, J. and De La Sen, M., Robust active control of base isolated structures including actuator dynamics

Makris, N. and McMahon, S., Structural control with controllable fluid dampers: Design and implementation issues

Matsuhisa, H., Nishihara, O., Takemoto, M., Yasuda, M. and Sato, K., Vibration control of a ropeway carrier by a dynamic absorber

Mita, A., Distributed health monitoring system for a tall building

Nakamura, Y., Tanaka, K., Nakayama, M., Sasaki, Y. and Fujita, T., Wind response observation of a slender building with a hybrid mass damper "Hirobe-Miyake Building"

*** Nigbor, R.L., State-of-the-practice in structural monitoring

Nikzad, K., Saberi Haghighi, K. and Ghafory-Ashtiany, M., A parametric approach to nonlinear structural identification using neural networks

Nishitani, A., Yamada, N., Nitta, Y. and Yamada, S., Concept of model reduction for structural control

Panariello, G.F., Betti, R. and Longman, R.W., Ensemble training of a structural controller for MDOF systems

Pines, D.J., A remote wireless infrastructure health monitoring system for damage assessment

Prell, A.P., Tsao, T.C. and Bergman, L.A., Application of repetitive control to vibration attenuation in civil engineering structures

Qi, K. and Xie, L.L., Time delay compensation with the identification of random ground motion acceleration for closed-loop structural control

Reed, D., Yeh, H., Yu, J.K. and Gardarsson, S., Performance of tuned liquid dampers under large amplitude excitation

*** Reinhold, T.A. and Kareem, A., Next generation of wind test facilities: A feasibility study

Robinson, W.H. and Monti, M.D., Dampling wind and earthquake induced motion - The New Zealand Experience

*** Sakamoto, M. and Kobori, T., Applications of structural response control (review from the past and issues toward the future)

Sato, T., Sato, M., Tanaka, S. and Toki, K., Modeling of a variable damper and its application

Seto, K. and Matsumoto, Y., A structural control of vibration method of flexible buildings in response to large earthquakes and strong winds

Shing, P.B., Rose, B., Dixon, M.E., Kang, S.D. and Kermiche, N., Application of active and semi-active devices for the control of building vibrations

Singh, M.P., Matheu, E.E. and Beattie, C., Output-feedback sliding mode control for civil engineering structures

Smith, H.A. and Schemmann, A.G., Modeling issues associated with vibration control of cable-stayed bridges subjected to multiple support excitation

Smith, R., Closed-loop modeling and control of civil structures - Robust control approaches ..

Straser, E.G. and Kiremidjian, A.S., A modular, visual approach to damage monitoring for civil structures

Sultan, M. and Sheng, L.H., Caltrans/FHWA program for the performance testing of seismic isolation and energy dissipation systems

Tsai, K.C., Seismic energy dissipators for performance-based design

Wilde, K., Fujino, Y. and Prabis, V., Effects of eccentric mass on flutter of long span bridges

Yoneda, M. and Miyachi, S.I., Aerodynamic countermeasures to suppress wake galloping in tandem cables of cable-stayed bridges

Yoshida, K. and Watanabe, T., Active vibration control system using base isolation and dynamic vibration absorber

Yuan,W.C. and Fan, L.C., Study and application of aseismic rubber bearings for bridges

3. List of Participants:

Participants who attended the Workshop (Format: Surname/Name; Address/Fax No./Email)

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4. WORKING GROUP RECOMMENDATIONS

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
Report of Working Group I:
Building Control

CO-CHAIRS: J.N. Yang (USA), K. Seto (Japan), C.S. Yeh (Taiwan)
RECORDER: B.F. Spencer, Jr. (USA)

GOALS AND OBJECTIVES

The main goal of the working group on building control is to initiate the development of a series of representative benchmark problems that can help to focus structural control research for buildings. However, since it is impractical, both financially and logistically, for all researchers in structural control to conduct experimental tests, development of high-fidelity analytical benchmark problems is an important task. Simultaneously, experimental benchmark problems should be formulated, including both small and large scale structures.

OUTLINE OF DRAFT PLAN FOR ANALYTICAL BENCHMARK PROBLEM

1. Analytical Model Development
   * Model should feature 3-D behavior.
   * A simpler 2-D model should be available.
   * Low, Medium and High rise buildings should be considered.
   * Building models will be rectangular in plan.
   * For now, focus will be placed on linear structures and steel construction.
   * The possibility of including nonlinear behaviors in the model should be considered.
   * Uncertainty is important and should be specified for the models.
   * Coupling should be included between lateral and torsional motion.

	L/W	H/W	Freq.	Damp.	# Story
Low	1.5	~2	2-5	~2%	5
Med	1.5	~3	0.5-1	~1%	15
High	1.5	~5	0.2	~0.5%	30

2. Loading

   Earthquake loading will be considered for all three classes of buildings. Both historical records and stochastic models for the ground motion will be considered.
   * For the stochastic representation, use the Kanai-Tajimi model with random Wg and Zg.
   * For historical earthquakes, use the El Centro, Hachinohe, Kobe and Northridge records.
   * Use three different levels of ground motion.

Wind loading will be considered for only the high rise building.
   * Use a stochastic model for the wind loading. Supplement with wind measurements as it becomes available.
   * Both along and across wind should be specified.

3. Sensors

   All sensors employed must include a model for sensor dynamics and noise.
   * Accelerometers
   * Velocity transducer
   * Displacement transducers

   Sensors that require further study
   * Optical fiber
   * Laser
   * Strain gage
   * Piezo films

   The number and location of sensors is to be determined by the respective investigator.

4. Actuators
   * Appropriate dynamic models of the actuator and fixturing necessary for implementation must be employed. The feasibility of the actuator for full scale implementation must be demonstrated.
   * Specify actuator force/stroke/velocity limitations and power/energy requirements.
   * The number and location of actuators is to be determined by the investigators.
   * Passive control (excluding base isolation) Viscous fluid dampers, Friction dampers, Viscoelastic dampers, Yielding dampers, Eddy current dampers, TMD/TLD.
   * Active control; AC/DC servomotors (e.g., ball-screw), Hydraulic, Electromagnetic, Piezo stacks, Pulse jets, Aerodynamic “wings”.
   * Semi-active control; Variable orifice dampers, ER/MR dampers, Variable friction dampers, Variable TLD, Variable stiffness dampers.

5. Control Hardware
   * Individual investigators should show that their control algorithms are implementable using available computing hardware.
   * Issues such as sample rate, precision of A/D and D/A converters, saturations and control discretization should be considered.

6. System Identification
   * System identification approaches should be based on measurements that are available in full-scale implementations.
   * Several approaches may be of interest, including:
     * Input/output models
     * Physical-state model
     * Lumped parameter models
     * Reduced-order models
       - maximum size of reduced order model
       - control + observation spillover

7. Evaluation Criteria
   * For stochastic excitation, use peak rms responses.
   * For historical records, use peak responses.
     * Power requirements
     * Energy requirements
     * Safety and Serviceability
       - interstory drift
       - floor acceleration
       - base shear
       - total energy input to structure
       - overturning moments
     * Hardware reliability
     * Control algorithm robustness
     * Actuator Force/Stroke/Velocity requirements
     * Mass ratio for AMD/HMD

* Overall reliability of controlled structure
* Economical considerations
  - total control system cost
  - space to install system
  - operation
  - maintenance
  - comparison with total cost of appropriately designed structure w/o control

<u>Proposal for the 2nd World Conference on Structural Control, 28 June - 1 July 1998 Kyoto, Japan</u>

* Organize several sessions focusing on the analytical benchmark problem for the 2WCSC.
* Make the analytical benchmark problem statement available by 1 June 1997.
* Have "anchor" participants:
* More sessions to be organized from contributed papers.

Experimental Benchmark Problems

* Both small and large scale benchmark experiments should be established.
* Low, medium and high rise models should be constructed.
* These models will be determined by the core working group.

Tentative List of Candidate Testing Sites Available to the Controls Community

* USA:
  - Large: UCI, NCEER, Berkeley
  - Small: ND, Wash. U, USC
* Japan:
  - Nihon University
* Other:
  - Large: NCREE, IHS-Beijing
  - Small: Pavia

*Additional sites to be determined.

* Also note that two full-scale, 5-story buildings are available in Taiwan for testing.

Future Tasks

* Development of Analytical Benchmark Problems
  - Computer models for low, medium and high rise buildings under earthquake loading for use in simulation, evaluation and design.
  - Computer models for high rise buildings under wind loads for use in simulation, evaluation and design.
* Development of Small-Scale Experimental Benchmark Problems
  - Development and construction of structural models for earthquake loading.
  - Development and construction of model structures for wind tunnel studies.
* Development of Large-Scale Experimental Benchmark Problems - A future effort.
* Resources should be sought to support the above activities.

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
Report of Working Group II: Bridge Control

CO-CHAIRS: A. Kareem (USA), T. Miyata (Japan), J. Rodellar (Spain)
REPORTER: L. Bergman (USA)

GOALS AND OBJECTIVES

The working group recognizes that the control of flexible bridge structures is a new, difficult and unique problem, with many ramifications, both in modeling and control design. The control of very flexible bridge structures has not been studied to the extent that buildings have. As a result, little expertise has been accumulated. There is a consensus within the working group that a benchmark problem at this stage would be premature.

ALTERNATE PLAN

* The working group proposes that a feasibility study be performed on a well-studied and documented bridge model, in order to identify and resolve important issues and problems associated with attempting to control a flexible cable-stayed bridge.
* Since the active control of medium and long span bridges has little history associated with it, the working group recommends that the study be as open-ended as possible.

MODEL DEVELOPMENT

* The working group proposed to focus on the Nam Hae bridge in South Korea, as previously modeled and extensively studied by Professors H. A. Smith and R. Shoureshi under a current NSF-sponsored contract.
* The working group selected this bridge over several other excellent candidates since verified models exist for both response evaluation and control design.
* Professor Smith will provide these models to the working group for the feasibility study.

SALIENT FEATURES OF THE PROPOSED BRIDGE MODEL

* Geometrically symmetric cable-stayed configuration.
* Geometry (span, deck width, tower height) defined.
* Material: steel.
* Geometrically nonlinear.
    ~ Equilibrium position found via static analysis.
    ~ Model is linear elastic for small motions about the equilibrium.
* A three dimensional FEM model exists consisting of approximately 320 degrees of freedom which correlates well with a more complex model developed at the University of Wales at Swansea under contract to the government of South Korea (Smith, et al., 1996).
* Model reduction issues have been studied and resolved, leading to the development of 24 DOF control-oriented models for in-plane and out-of-plane deformations (Smith et al.,

1996).

* State space models have been developed for control design (Smith, et al., 1996). Control issues remain, however, which is an ideal point of entry for our study.

LOADINGS

Several types of loading will be considered.

* Seismic
  ~ Kobe earthquake (historic); scaling to be determined.
  ~ Capacity for multiple support excitation is included in the model.
* Wind
  ~ Vortex excitation only will be considered; magnitude to be determined.
  ~ Spectral model to be specified.
  ~ Flutter and buffeting will not be considered at this stage.

EVALUATION CRITERIA

* The working group believes that the study must remain as open-ended as possible since there is little prior experience in the active control of cable-stayed bridges. The group believes the imposing rigorous evaluation criteria on the study at this time will be a deterrent to participation.
* The efficacy of a candidate controller will be assessed by its ability to reduce critical forces and moments, and associated displacements and rotations, for given control effort when compared to the system without control.

SENSORS

* Direct measurement of accelerations, velocities, and strains will be presumed. Direct measurement of displacements will not be accommodated.
* Measurement locations.
  ~ Sensors must be placed at the quarter-spans and at mid-span.
  ~ Other locations are by discretion of the participants.
* Sensor noise and dynamics should be considered where applicable.
* Further guidelines will be formulated and furnished to the participants.

ACTUATOR MODELLING

* Due to lack of experience and information, the working group felt that no actuator possibility should be summarily excluded. However, participants will be required to identify types of actuators used in their designs and to model them appropriately.
* The number of actuators and details concerning their implementation will be left open for this study. Active, semi-active, and hybrid (passive/active and passive/semi-active) systems will all be considered acceptable solutions.
* Details such as attachments and actuator limitations such as saturation will be considered beyond the current scope of this study.

CONTROL HARDWARE

* Details concerning control hardware will be considered beyond the scope of the current study.

CONTROL ALGORITHMS

* Algorithm selection will be left to the discretion of the participants.

ECONOMIC CONSIDERATIONS

* These will not be considered in the feasibility study.

PLAN FOR 2WCSC

* The working group envisions one session of 4 or 5 papers focusing on results of the study. Participants will be drawn from a core group, to be identified.
* A second session of 4 or 5 papers will be added if there is sufficient participation.

LARGE SCALE EXPERIMENTS

* The working group felt that consideration of experimental aspects of cable-stayed bridge control would be premature at this time.

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
Report of Working Group III:
Health Monitoring

CO-CHAIRS: S. Yamamoto (Japan), R. Nigbor (USA), J.C. Chen (Hong Kong)
REPORTER: J.L. Beck (USA)

GOALS AND OBJECTIVES

The working group was charged with the preparation of plans for a series of international benchmark studies of proposed methodologies for structural health monitoring using response data from full-scale structures in damaged and undamaged states.

For the purpose of working towards this goal, the group defined a structural health monitoring system as any non-destructive evaluation technology for damage detection, location and/or assessment using structural response data.

The group decided on a strategy of preparing a short-term plan which focuses on a benchmark comparison session at the Second World Conference on Structural Control (2WCSC), 28 June - 1 July 1998, and a longer-term plan which involves additional steps that will improve structural health monitoring practice.

SHORT-TERM PLAN

The goal of the short-term plan is to prepare benchmark tests to compare data analysis and identification algorithms for structural health monitoring which would culminate in a special session at 2WCSC.

Test Data:
The group decided that the benchmark comparisons should be performed using both real and synthetic structural response data.

* Real structural data
  In this case, the data provided to the benchmark study participants will consist of frequency response functions from a decommissioned bridge which has been tested in various damage states, such as the I-40 bridge near Albuquerque in New Mexico which was tested in 1993, or the Seymour Avenue Bridge in Cincinnati, Ohio, which was tested in 1996.
* Synthetic structural data
  In this case, the response data will be generated numerically from a finite-element model of a multi-story steel-frame building and will have the following features:
  - Represent simulated small-amplitude ambient vibrations
  - Consist of acceleration time histories at each floor
  - Several known damage scenarios given, including multiple damage locations as well as damage at single locations
  - Several blind damage scenarios given but in each case, damage will be at only a single location
  - "Damage" will be stiffness loss at a connection due to fracture at a flange and/or web
  - Baseline data from the undamaged structure will also be provided

Plan Outline:

* Open invitation for participation issued as soon as possible
* Provide structural drawings for the chosen bridge and building so that participants can develop their baseline models by mid-1997
* Benchmark test data supplied via Internet FTP by mid-1997
* Results and method submitted as papers a month before 2WCSC
* Blind test damage scenarios released soon after this date
* Presenters discuss reasons for success or failure during the special session at 2WCSC

Several members of the working group expressed interest in being participants in the benchmark comparisons.

LONGER TERM PLAN

The goal of the longer-term plan is to improve structural health monitoring technology by a series of additional activities.

Plan Outline:

* Set-up a Structural Health Monitoring Committee under IASC to pool resources, share data, and provide an international forum to address issues for further technology improvement. The 18 participants in the working group would serve as core founding members.
* The committee will perform a critical examination of all the components of a structural health monitoring system:
  - sensors

- actuators (for forced vibrations tests)
- data acquisition
- data communication
- data analysis and identification methodologies

* The committee will prepare a plan for targeting and responding rapidly to opportunities for future benchmark tests of damaged or decommissioned civil structures, and possibly special laboratory structures which can be damaged and repaired

Discussion of Health Monitoring System Components:

The group had an open discussion about needs and issues for each of the major sub-systems or components of a structural health monitoring system:

1) Sensors:

* High-dynamic range (120db) force-balance accelerometers for ambient vibration tests are now available at modest cost (about $400 US). The current generation of cheap solid-state sensors (e.g. used in automobiles) does not give sufficient dynamic range
* Fiber optics should be considered. (A system installed in a R/C building at the University of Vermont has several miles of fiber optic cable)
* Direct displacement sensors should be considered. (Current laser systems are too expensive; GPS can only be used at very low frequencies with resolutions of the order of a cm up to 5Hz)
* Methodologies for optimal sensor placement for damage detection need to be addressed

2) Actuators:

* Forced vibration tests are appropriate for bridges, but are less so for commercial buildings. (Methods which have been applied include impact hammers, moving trucks, rotating masses, AMD, etc.)
* Ambient vibration tests are efficient, low-cost and non-obtrusive but they give a poorer signal-to-noise than forced-vibration tests

3) Data Acquisition:

* Data acquisition systems using 19-bit A/D are now state-of-the-art (e.g. there are commercial systems using 24-bit DSP chips with 1MHz front-end sample rate so analog anti-aliasing filters are not needed
* Sample rates at the back-end of 100-200 Hz are adequate, depending on the structure
* During ambient vibration tests, time-history data should be saved even if power spectra are computed in real-time during the tests

4) Data Communication:

* Current implementations are moving from twisted wire cables to fiber optic cables or local radio communication
* New applications are emerging which use the Internet
* The format for data exchange needs to be considered. It would be of value to develop an International Standard for this

5) Analysis/Identification:

* Global methodologies must treat an ill-conditioned and non-unique inverse problem due to:
  - lack of sensitivity of the structure's dynamic characteristics to local stiffness loss
  - limited number of sensors
  - limited response bandwidth
  - measurement noise
  - modeling errors
* Precise determination of damage may not be feasible, but an indication of its likely location and severity would be valuable
* Adaptive substructuring techniques can be used to enhance the sensitivity to damage
* Global methodologies can complement local NDE tools e.g. X-rays, ultra-sonics, etc.

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
Report of Working Group IV:
Case Studies in Control

CO-CHAIRS: H. Iemura (Japan), M. Riley (USA), W. Robinson (New Zealand)
REPORTER: H. A.Smith (USA)

GOALS AND OBJECTIVES OF COLLECTING CASE STUDIES:

(1) to provide a formal and organized means of documenting structural control implementation results

(2) to allow usage of selective case studies as examples for verification, illustration, and comparison in structural control research

(3) to increase awareness of control technology by providing a venue for illustration of realistic control case studies and results

INFORMATION NEEDED FOR THE CASE STUDIES:

There will be two categories of information provided for the control case studies:

(1) documentation information; and

(2) technical information.

Documentation information will consist of general information about the control case study and will not list any specific technical information. It is hoped that this category will eventually be a complete listing of all structural control case studies in civil engineering. For those case studies for which additional technical information can be provided, some or all of the following details are desirable, including all technical details, results from prior studies, and all relevant information needed by other researchers to use that case study for simulation, verification, and comparison purposes.

The documentation information will consist of:

General Information

(1) Name of project
(2) Type of structure (building, bridge, or lifeline)
(3) Location of structure
(4) Date of construction
(5) Description of structure's geometric configuration and construction materials
(6) Photograph
(7) Structural designer and retrofit designer (if applicable)
(8) Building contractor
(9) Controller designer
(10) Control system contractor
(11) Excitation to be controlled (i.e., wind and/or seismic)
(12) Contact person or group responsible for structure/controller system

Realizing that proprietary concerns could inhibit the sharing of certain technical information, the following information is optional for each case. However, for those case studies where the information is available, the list of information continues:

Controller Information

(13) Control objectives (i.e., control of damage, human safety, human comfort, etc.)
(14) Type of actuator (control hardware)
(15) Type of control algorithm used in design (software)
(16) Controller capacity (force)
(17) Controller energy consumption requirements
(18) Power supply
(19) Special features
(20) Maintenance needs

Monitoring/Instrumentation Information

(21) Location of instrumentation
(22) Type of instrumentation
(23) Type of monitoring system

Modeling Information

(24) Structural model used in design
(25) Controller model used in design

Results from Prior Analyses

(26) Numerical simulation results
(27) Performance of controller and structural response from "real-life" loadings
(28) List of publications/reports referring to structure/controller system

USER OF CASE STUDY INFORMATION

academia
industry

MEANS OF GATHERING CASE STUDY INFORMATION

* Development of a case study registry made available through IASC
* IASC Web site and newsletter
* Possible publication of written report summarizing case studies

PLAN FOR GATHERING CASE STUDY INFORMATION

Several IASC members have expressed interest in helping gather the case study information.It is the responsibility of each volunteer to begin the collection of the case study information available in their country. This effort is expected to take several months to start and will require constant updating of information. In upcoming meetings, the IASC will address additional issues associated with the maintenance of the case study registry. Updated information on the status of the Case Study Registry will be available on the IASC Web site and in the upcoming IASC newsletter to be published this spring.

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
Report of Working Group V:
Design Philosophy for Control Codes

CO-CHAIRS: Y. Kitagawa (Japan), M. Sultan (USA), F. Casciati (Italy)
REPORTER: W.D. Iwan (USA)

GOALS AND OBJECTIVES

The Working Group concludes that the following steps need to be taken relative to design codes and standards for controlled civil systems:

1. Amend existing codes to allow use of performance-based control

Existing structural codes for buildings and bridges should be amended as needed to allow for the use of control methodologies, provided these can be shown to provide equal or better performance as conventional design approaches. This implies that the codes must have provisions for "performance-based" approaches to design that include both life-safety as well as economic performance objectives. Generally speaking, control methodologies are not currently being used to achieve life-safety performance objectives. Therefore, a major shift in thinking regarding the use of such methodologies will be required.

2. Establish a process to assure performance

A process needs to be established in order to assure that equal or better performance is achieved using control. This process will need to address the following issues:

a) hazard specification including any unusual loads such as near-field/source effects,
b) quality control/assurance for the control system including qualification of vendors, material and equipment specifications, testing requirements, etc.,
c) system reliability and serviceability, and

d) peer review by an interdisciplinary, professional body.

The peer review group will need to address such issues as the adequacy of computer modeling and the treatment of system uncertainties, and the appropriateness of the assumptions upon which computer models are based. The peer review group should take into consideration the results of benchmark studies and case studies of previous control projects.

3. Develop a design philosophy

There is an urgent need to develop a philosophical basis for the use of control methodologies that will both promote the increased use of these methodologies and assure that the performance of controlled structures is not compromised relative to uncontrolled structures.

One possible approach to establishing a philosophical basis for the use of control would be to establish strength, ductility, or other credits for the use of control which are tied to different levels of performance. An example of credits for the use of control is given in the table:

Example of possible credits given for use of control.
Percent of reduced ductility demand allowed to be used in design

Performance Level	Credit
Level 1 (Functionality)	70%
Level 2 (Life Safety)	30%
Level 3 (Collapse)	No credit

4. Prepare draft performance-based design guidelines

Guidelines should be prepared that set forth the basic principles that need to be used in design of structures using control methodologies. These guidelines should set forth recommended approaches for dealing with such issues as hazard specification, quality control, reliability, liability, redundancy, maintenance, deterioration, control system capacity, power requirements, component testing, and component certification. They should be in the form of general recommendations rather than prescriptive rules. Flexibility is important in order to encourage continued innovation in the application of new concepts and technologies.

Design guidelines for base isolation are currently being developed. These guidelines should be updated where necessary to insure that they are performance-based in their approach. Further study will be needed before general guidelines can be developed for active control, TMD, and TLD systems.

Much of the current impetus for code and guideline development relative to base isolation, has resulted from pressure by vendors of isolation devices. At present, there is not strong vendor pressure in the areas of active control, TMD, and TLD. As such systems receive wider use, this pressure will no doubt increase.

Implementation

The IASC should create a Task Group on Design. This Task Group should be charged with undertaking the following tasks:

1. survey and summarize existing codes and guidelines for base isolation and passive damping control systems, including those of Japan, CALTRANS, ATC-33, SEAOC, etc.,
2. develop a general philosophical basis for the use and design of structural control systems, and
3. recommend a draft outline of guidelines for the design of structural control systems including base isolation, passive damping, TMD, TLD, and active control systems.

The Task Group should make a report to the 2WCSC.

SECOND INTERNATIONAL WORKSHOP ON STRUCTURAL CONTROL
Report of Working Group VI:
Future Directions for IASC

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1. Future Directions in Structural Control
   Research (see Figure 1: Future Directions for IASC)
   Development
   Applications (see Figure 2: Integrated Earthquake Hazard Mitigation)

2. Recommended Goals
   Short-Range (1-5 years)
   - application of passive devices
   - active control of small oscillations
   - health monitoring

   Long Range (> 5 years)
   - economic retrofit/new structures applications
   - control systems for large earthquakes and wind
   - damage detection
   - outline of design code philosophy
   - collaborative experimental activities

FUTURE DIRECTIONS FOR IASC

3. Role of IASC
   Facilitate Coordination of International Activities

Promote Field of Structural Control
- Information dissemination (Newsletter; Journal)
- International meetings (Workshops; Conferences)

Facilitate Applications
Establish Task Forces to Implement Recommendations
Assist in Establishment of Regional Panels

Two Diagrams:

* Fig 1. Future Direction of IASC (Standpoint from Earthquake Engineering)

* Fig 2. Real-Time Integrated Earthquake Hazard Mitigation