EARTHQUAKE ENGINEERING FOR SEISMIC DISASTER MITIGATION IN THE 21st CENTURY

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Kobe, Japan January 2005

San Francisco, 1906

Taken from EERI Quake 06 web page

Kanto, 1923

Photo by A Kengelbacher

CURRENT CHALLENGES IN SEISMIC RISK REDUCTION AROUND THE WORLD

- **Technical (Engineering):**
  - ✓ Hazard assessment
  - ✓ Understanding cyclic behavior of materials, structural members and complex systems
  - ✓ Response and performance predictive models
  - ✓ Vulnerability analysis
  - ✓ Optimum design criteria
  - ✓ Practical analysis and design algorithms

CURRENT CHALLENGES IN SEISMIC RISK REDUCTION AROUND THE WORLD

- **Societal:**
  - ✓Risk perception
  - ✓Socio-economic priorities
  - ✓Access to technical resources

    Code development, implementation and application

    Non-engineered construction
  - ✓ Land use regulations and practice

Our actions must respond to both groups of challenges!

Technical

Societal

EARTHQUAKE ENGINEERING IN 2005
An overview of technical accomplishments …and challenges

- Spectacular progress during last half century
  - ✓ Understanding of physical phenomena:
    - Earthquake generation and propagation
    - Structural response
  - ✓ Complex and powerful mathematical models
  - ✓ Computational resources

- Insufficient impact of these advances on practical design applications:

  Complexity, dissemination, non-engineered constructions

- **Every new earthquake teaches new lessons!**

Lessons from recent earthquakes

- A large portion of life losses and economic consequences are blamed on
  - ✓ *Obsolete building codes*
  - ✓ *Careless design*
  - ✓ *Faulty workmanship*
  - ✓ *Deficient quality control*
- Each new earthquake brings new surprises
  - ✓ *Discloses previously ignored sources of increased hazard, vulnerability and risk*
  - ✓ *Calls attention about previously unnoticed risk enhancing concepts*

This is true even for regions that count with modern technology and wide economic resources!

Confronting reality

- Frequent mal performance of large numbers of struc… e with state-of-th…

The more we learn, the more we realize how much remains to be learned!

- ✓ *Prev…*
- ✓ *Larg…*
- ✓ *Abn…*
- ✓ *Abnormal frequency content*
- ✓ *Concealed mechanical weaknesses*
- ✓ *Deterioration due to previous events or differential settlements*
- ✓ *Inadequacy of ordinarily accepted engineering tools*

…………..

Recent experiences:
Witnesses of unjustified optimism

- Mexico City, 1985
- Northridge, 1994
- Kobe, 1995

Mexico City before 1985

- 1957: first severely damaging earthquake
  - ✓ *5 buildings collapsed*
  - ✓ *Selective influence of local soil conditions on moderate and long period structures*

- Lack of previous experiences
  Aztec and Spanish colonial constructions had remained unscathed

- Major code revisions in 1957, 1966, 1976

All inspired confidence!

Mexico City, 1985

From EERI photo gallery

Mexico City 1985:
Collapsed optimism

- Second largest magnitude near the Southern coast of Mexico during XX Century
- Long epicentral distance: 360km
- Low near-source peak ground accelerations
- Abnormally high energy radiated in the direction of Mexico City, in frequency range similar to that of local soil formations
- Extremely high local amplifications

Mexico City, 1985
Lessons about structural response

- Discrepancies between observations and nonlinear response estimates in up-to-date design practice
  - ✓ *Irregular variation of strength and stiffness along building height*
  - ✓ *Soft stories*
- Survival of apparently weak systems
  - ✓ *Contribution of non-structural elements to lateral strength and energy dissipation capacity*

Northridge, 1994

From EERI photo gallery

Northridge, 1994

- Shock generation and propagation: directional effects
  - ✓ High velocity pulses

Significant recent advances in models of fault rupture and wave propagation!

- Fatigue damage on welded connections in steel structures

Are we paying enough attention to damage accumulation for life cycle system reliability?

Northridge, 1994: More lessons

- Significant economic losses and disruption of functionality associated with equipment, content and essential facilities
  - ✓ They might have been easily prevented at very low cost!
- Satisfactory performance of
  - ✓ Base isolated structures
  - ✓ Bridges retrofitted after San Fernando, 1971
- But: failure of cable restraint units and collapse of girders after sliding off their supports

Kobe, 1995 (Hyogo Ken Nambu)

From EQE Summary Report

Kobe, 1995

- Strike-slip fault rupture directly into downtown Kobe
- Near-fault significant directivity effects: *few large velocity pulses*
- PGA ≈ 0.8g on alluvial sites *(comparable to California)*
- Last previous large magnitude earthquake: 1948

Most damaging earthquake in Japan since Kanto (1923)

Kobe, 1995

- Seismic code revisions: 1971, 1981
- Observed damage depended significantly on the design code used
- Foundation failure, liquefaction
- Column failure produced by vertical ground accelerations
- Reinforced concrete joints, shear failure in columns
- Pancake failures at midheight stories of multistory buildings
- Large viaduct structures

Last decades: an overview

Spectacular progress

Still, significant limitations

Lessons from earthquakes

Modern Earthquake Engineering: Present and near-future challenges
A brief summary

- **Seismic hazard analysis**
- **Vulnerability and risk**
- **Practical design criteria and methods**

Seismic hazard analysis

Need to understand similarities and discrepancies between

- **focal mechanisms**
- **regional and local Geology**
- **wave propagation and amplification patterns**

in the vicinity of different seismic sources in the world.

- ✓ *3D valleys*
- ✓ *Monte Carlo simulation*

Vulnerability and risk

- Nonlinear response models for complex systems

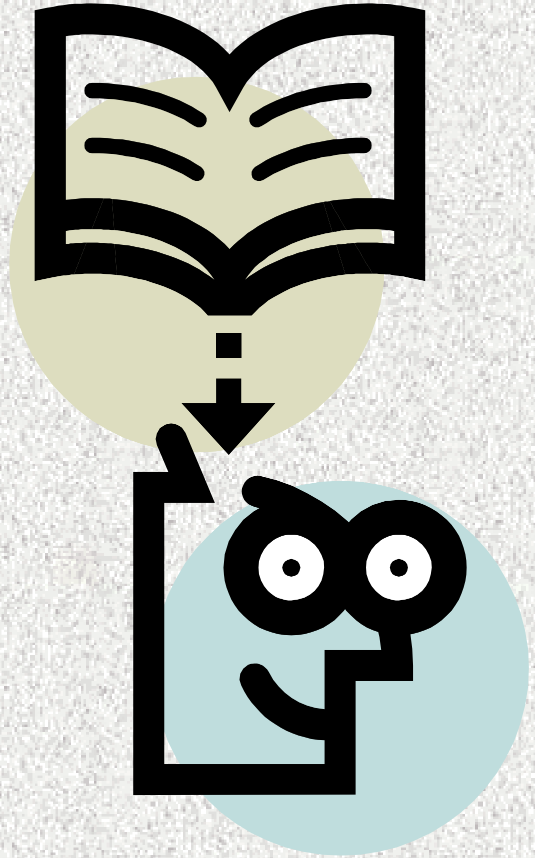
Need for experimental information about nonlinear dynamic response and performance of structural members and complex systems

- Active and passive control devices, for construction of new systems and retrofitting of existing ones

Practical design criteria and methods

- Alternative approaches to nonlinear response prediction and design acceptance criteria
  - *Detailed system models*
  - *Simplified models applicable to generic systems: accounting for spatial variability of strength and stiffness*
  - *Simplified models applicable to general cases*
  - *Response and capacity transformation factors, dependent on uncertainty associated with response and capacity prediction models*
- Friendly, efficient and transparent software

Just a limited picture…



Only a few of the technical problems in Earthquake Engineering that require attention have been presented.

Many of the solutions may be applicable to conditions typical of many regions and countries.

Magnitude and diversity of challenge call for coordinated efforts of academics and professionals around the world.

Earthquake Engineering challenges related to socio-economic conditions

Recent disasters:

Gujarat, 2001

Bam, 2003

Related IAEE activities

- **Basic concepts for seismic codes (1980)**
- **Guidelines for earthquake-resistant non-engineered construction (1987, 2003)**
- **Housing Encyclopedia (EERI, 2002)**
- **New IAEE initiative for assisting developing countries (2002)**

New IAEE Initiative for Assisting Developing Countries

- Earthquake risk in developing countries has been increasing with time.
- Any initiatives may take a long time before concrete results emerge.
- The problem is not just one of lack of financial resources, but also of social attitudes….
- Effective actions should emerge from within the country; not suggested from outside.

IAEE role: Motivator

Facilitator of programs adopted by local authorities and executed by local professionals

IAEE program considers actions along three directions:

- Sensitization towards earthquake mitigation issues
- Human resource development
- Information dissemination

Desirable sensitization actions addressed to leadership of developing countries

- Recognize the severity of the earthquake risk problem and the need for adequate manpower and institutional framework.

- Specific actions to be promoted by IAEE:
  - ✓ *Workshops with the help of overseas experts*
  - ✓ *Review by competent persons about the actual earthquake risk situation*
  - ✓ *Dissemination about the state of earthquake engineering and advisable future directions*

Sensitization towards earthquake mitigation issues

- Handicaps:

- Numerous pressing and urgent problems:
  - ✓ *Basic education, medical facilities, shelter, employment*

- Wide variety of construction typologies

- Inadequate engineering techniques:
  - ✓ *Seismic safety not demanded by client*
  - ✓ *Non-existent or primitive seismic codes*

Development of human resources

- Availability of human resources; a spectrum of possibilities:
  - ✓ *Significant earthquake risk; no internal expertise*
  - ✓ *Earthquake Engineering formally established; not enough experts or capacities*
  - ✓ *Some leaders; no encouragement or opportunities for development of younger generations of experts*

Earthquake Engineering
Information resources

- Earthquake Engineering is rapidly evolving
- International publications are often too expensive for the standards of developing countries
- IAEE actions
  - ✓ EESD publisher's donations to developing countries
  - ✓ Stimulate publication of material closely related to applications in conventional practice
- Other possibilities
  - ✓ Links giving access to up-to-date material from leading organizations

CONCLUDING REMARKS

Earthquake Engineering challenges around the world:

- Knowledge improvement:
  - ✓ *Seismic excitations: multi-component, local conditions, near-source wave propagation…*
  - ✓ *Structural response and performance*
- Practical analysis and design methods
  - ✓ *Theoretical models*
  - ✓ *Reliability and optimization basis*
  - ✓ *Simplified criteria and models: development and calibration*
- Knowledge dissemination
- Socio-economic conditions

CONCLUDING REMARKS

Need to enhance international collaboration

- ✓ Efficient information-sharing systems:

  Ground motion records

  Structural response and performance (damage data bases: in situ, laboratory)

- ✓ Coordinated research programs *(access to modern facilities)*

- ✓ Regional cooperation *(similar problems)*

- ✓ Education and training

The challenge is big!

We have to join forces!

The world has become very small!

Thank you!

Hokusai: Great wave