Group C-Seismic Design

Date: November 14 and 15, 2000
Place: Tsukuba International Congress Center
Chairpersons: K. Ohi and H. Krawinkler （S. Goel on 15th）
Secretaries: M. Teshigawara and Y. Mukai
Members: See Attachment Participants List Group C: Seismic Design

SUMMARY OF DISCUSSION

In the session of group C, 15 papers were presented and related discussions were conducted about following sub-categories; 1.Seismic Limit State, 2.Seismic Demand, 3.Seismic Capacity, and 4.Other Issues

In the sub-category of Seismic Limit State, two papers were presented and discussions were conducted about following issues.

1. Other limit states than conventional two categories (Ultimate safety and Serviceability)
   Repairable or not, Immediate functionality (hospitals, refuges)
   Non-structural elements
2. Consideration of aftershocks
3. Which is damaged first preferably, upper structure or foundation
4. Diversity of opinions on limit states or damage tolerance among researchers, designers, owners, users,･･･.

In the sub-category of Seismic Demand, six papers were presented and discussions were conducted about following issues.

1. Limitations, robustness and implementation of simplified analysis (Check of time history analysis), Irregularity in plan and elevation, Designer friendly analysis.
2. Near-fault event vs. far-field event, uncertainty of ground motion
3. Higher mode consideration in load pattern used in pushover analysis, and detection and assurance of failure modes. Which is target failure mode? Also in assessment of existing structures
4. SSI consideration: a whole analysis vs. a separated analysis. Uncertainty of soil conditions

In the sub-category of Seismic Capacity, five papers were presented and discussions were conducted about following issues.

1. Sometimes hard to divide design variables into Demand and Capacity (history-dependent), Just Acceptance Criterion $g(d1,d2,\cdots)>=0$
2. Consensus making and optimization about description of acceptance criterion w.r.t. design procedure as well as performance level.
3. Implementation of experimental techniques
   - # Prescribed loading program is OK to assess member deformability?
   - # Role of full-scale response test?
   - # New material, new devices for structural control

In the sub-category of Other Issues, two papers were presented and discussions were conducted about following issues.

1. Control of performance
   - Control in design process; Failure mode control, passive vibration control
   - Real time control (active)
2. Against accidental action, human errors
   - Robustness (Insensitivity) to various design and workmanship errors
   - Fail-safe system, double protection to collapse

3. Maintenance, sustainability
   - Damage sensor; Health monitoring system
   - Aging, environmental effects

RECOMMEDATION

Research Needs:

1. Limit states (performance levels) need to be refined and well defined. The ultimate limit state had to do with collapse, and the safety against collapse should be explicitly predicted. One reason is to evaluate the effect of aftershocks. In order to improve collapse safety, it should be assured in the design process that desirable and robust deformation (failure) modes occur. The usefulness of incorporating other performance levels (limit states), such as serviceability, reparability, continuous operation (e.g., hospitals), in the design process should be further evaluated.
2. The cost of earthquake damage is strongly affected by the performance of nonstructural (e.g., architectural, mechanical) and content systems. Explicit consideration should be given to the performance of these systems, and procedures should be developed to minimize the total life-cycle costs.
3. Uncertainties in the intensity and frequency content of ground motions have an overwhelming effect on the reliability of structures. This applies particularly to near-fault ground motions of the type recorded in recent severe earthquakes, such as the Northridge, Kobe, Chi Chi, and Turkey earthquakes. Research is needed to identify and quantify ground motion parameters that provide a more comprehensive measure of the seismic hazard for performance-based seismic design.
4. The system subjected to bedrock motions consists of the soil underlying the structure, the foundation system, and the structural system. These three subsystems should be treated as a coupled soil-foundation-structure system. Research is needed to identify the interactions between these subsystems and to develop a consistent approach to reliability-based design and performance evaluation that considers these interactions.
5. Design and performance evaluation should consider the uncertainties inherent in ground motions and in response predictions. The most accurate approach to performance evaluation is nonlinear time history analysis of the soil-foundation-structure system subjected to statistically representative sets of bedrock ground motions. In the near future, such an approach is unfeasible for most engineering applications. The need exists to develop simple but robust demand prediction methods that can be used for design and approximate performance

assessment. Research is needed to develop such approximate methods, which should account adequately for the intensity and frequency characteristics of the bedrock ground motions, for the soil site effects, and for the dynamic response characteristics of the structure. The limitations of the applicability of such approximate methods need to be established, particularly in the presence of irregularities in plan and elevation.

6. Reliability-based performance assessment requires realistic modeling of the cyclic constitutive (force-deformation) relationship of the individual elements that make up the soil-foundation-structure system, and analytical tools that provide reliable response predictions of this system. This necessitates the development of a comprehensive tool kit that permits prediction of all demands needed for a comprehensive performance assessment of structural and nonstructural systems. Analytical techniques are not sufficient to provide confidence into performance predictions. Experimental verification (and field observations) should form an essential part of the calibration process of such techniques.

Implementation Needs:

1. In most cases, implementation of PBD in engineering practice should be based on simple but transparent and first-principles-based procedures. The limitations on the applicability of these procedures must be clearly identified. Elaborate performance assessment can be justified only for special structures such as high-rise building and facilities in which failure to attain specified performance objectives will have severe consequences.
2. Extensive educational efforts are needed to communicate the intent of PBD to all stakeholders (public officials, owners, building trades professionals, and society at large), and to communicate the processes and procedures of PBD to teachers and practitioners involved in implementation (educators, architects, engineers, seismologists, etc.).
3. Successful implementation of PBD will necessitate the collaboration of all individuals and organizations involved in planning, design, and construction of buildings. In particular, the quality of construction will have a great affect on performance. Quality assurance procedures should be developed that will maximize the likelihood that the final product will perform as intended.

LIST OF FUTURE NEEDED RESEARCH

- Definition, Quantification of performance objectives (Acceptance/ Target Limit States) in terms of response parameters.
  - Structural components
  - Non-structural components
  - ➢ Drift, Deformation
  - Contents, Machinery,
  - ➢ Acceleration
  - Foundation - soil

- Drift, Deformation, (Acceleration)

- Demand; Design and Loading Development
  - Analytical (Relative member proportioning, Energy Dissipation Elements)
  - Experimentally Valid (Components, Full Structure).
- Capacity:
  - Definition (Strength, Deformation, Damage)
  - Also loading dependent Experimental/Test determination. Analytical models

- Methodologies:

Analysis – Models
Design, evaluation – Structure Components Detailing (Fabrication, Caution, etc.)
Preferred Mechanism
Plastic/Mechanism methods

- Social – Economical issues:
  - Cost/Benefit analysis(Risk tolerance)
  - Damage estimates
  - Life cycle costs
- Construction, quality control
  - Team concept, management
  - Reparability, costs
- Hazard levels: Definition

Earthquakes – Main event
After-shocks
Condition Assessment
Re-occupancy
Immediate (Emergency)
Repair work

- Simplicity, Transparency
- Implementation
- Education