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13th World Conference in Earthquake Engineering 2004 – Caribbean Implications and Recommendations

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The 13th World Conference in Earthquake Engineering (13WCEE) was held in Vancouver, British Columbia, Canada from 1st – 6th August, 2004. Attended by 2,400 delegates from 52 countries, 2,421 presentations were sub-divided into 30 categories. This event is the premier source for the state-of-the-art information in Earthquake Engineering (EE) in the world and is a major determinant for setting the direction for future developments. Given the significant seismic hazard in many of the Caribbean's territories, there are implications for the developments of Earthquake Engineering in the region. In this paper, implications and recommendations are presented in terms of research and practice and with respect to what is perceived as the main directives that should be adopted by the relevant regional authorities. A major finding is that the gap between the current state of the Caribbean R&D and practice in EE and the required levels for optimal safety, cost-effectiveness and international inclusion has increased significantly and must be addressed with a sense of urgency.

Keywords: Earthquake engineering, earthquake resistant design, design criteria, seismic code, performance-based earthquake engineering.

1. Introduction

The 13WCEE was held in Vancouver, British Columbia, Canada from 1st – 6th August, 2004. The WCEE is held every four years and is recognised as the premier international event for the presentation and exchange of information and ideas by researchers, academics, practitioners and government officials in the field of EE. Attendance at the WCEE is the only way to obtain state-of-the-art information on EE since it usually takes about 18 months to two years before becoming available as reference material (i.e., texts, published reports, etc.) for professional or academic use.

The 13WCEE was attended by approximately 2,400 delegates from 52 countries. There were 11 keynote presentations, 750 15-minute oral presentations and 1,660 6-hour poster presentations sub-divided into 30 topics. Perusal of the presentation titles and the overall feel of the presentations indicate that the following is an approximate summary of the focus of attention.

- Structural Analysis, or Structural Design Criteria – 30%
- Seismological, Geological, or Geotechnical Issues – 25%
- Analytical or Experimental Performance of Earthquake Resisting Sub-assemblages or Materials – 20%
- Lifeline Systems –15%
- Social and Economic Issues, and Directions for the Future (e.g., Future Codes, Lessons from Recent Earthquakes, etc.) – 10%

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2. Structural Analysis or Structural Design Criteria

The following observations are mainly due to recent code efforts to increase the reliability of damageability calculations and code-based recognition of the viability of passive controls.

There are three main trends in this area. Firstly, there is the refinement of the Displacement-Based Design approach and secondly, the refinement of Pushover Analysis. Both of these thrusts are moving towards the adoption of these methods in standard design office practice and are major developments. This is also evident in FEMA 356 — "Pre-Standard and Commentary for the Seismic Rehabilitation of Existing Buildings", and Appendix D of SEACO 1999. The presentation by **Guyader** and **Iwan** [2] provides an overview of one of the more popular displacement-based design approaches, the Capacity Spectrum approach and recommendations for improvement. The paper by **Goel** [3] is a comprehensive assessment of current Pushover Analysis methods.

Thirdly, there is a very significant increasein the refinement of the analysis and design of supplemental damping and base isolation devices. The Japan Society for Seismic Isolation (JSSI) presented seven papers outlining the contents of its 12-chapter manual [4] for building design and construction using passive controls which is probably at this time the most comprehensive document on earthquake resistant design by viscous damping in the world.

There is also a substantial increase in the development of probabilistic methods, especially the development of fragility curves, an example being the work of **Lupoi *et al***. [5]. In this paper, the development and application of a relatively inexpensive procedure is presented for structural systems in general.

3. Seismological, Geological or Geotechnical Issues

This is a wide field and covers such topics as interaction effects, local effects, lateral pressures, on-site test methods, etc. There is a very substantial increase in the study of local mechanisms, including geological factors and fault mechanics, for the development of design spectra, site characterisation and hazard analysis. This appears to be largely due to the requirements of recent codes such as the IBC 2003 where, for example, a site-specific study is required for soil sites designated as Classes E and F and procedures are recommended for the development of deterministic spectra given sufficient information on fault activity. Very informative presentations are the keynote paper by **Atkinson** [6] in which a review of developments in hazard analysis is discussed, and the paper by **Kawase** [7] in which the importance of considering surface geology in estimating strong motion is presented. Lastly, **Atakan *et al.*** [8] analyse the recent European SEASAME project with respect to the H/V spectral ratio technique for assessing site-specific effects.

There is also a significant increase in the study of soil-structure and fluid-structure interaction phenomena for the substructure/superstructure effects on significant building structures and non-building structures (bridge piers, offshore, harbour facilities, tanks). For example, there is the paper by **Ghannad *et al.*** [9] which reports on the effect of soil-structure interaction on the seismic strength reduction factors. **Rha *et al.*** [10] present a study on the analysis of soil-structure interaction for bridge columns.

4. Analytical or Experimental Performance of Earthquake Resisting Sub-assemblages or Materials

This area will always be fertile since this is where conceptual design innovation manifests as new ways to control the energy dissipation. The major trend is new passive control devices and systems using such devices. As examples, **Ishigakhi *et al.*** [11] describe the performance of a new toggle damper applied to historical timber structures. **Ciampi *et al.*** [12] investigate the application of passive controls in a number of scenarios for industrial process plants and **Doice *et al.*** [13] examine the issue of developing regulations for base isolation and passive controls for Italy and Europe.

There is also a very significant increase in the characterisation of both standard prescriptive and new, innovative systems along the fall range of behaviour, in keeping with the shift in the design paradigm to performance-baseddesign under displacementcontrol. Towards this end, **Clarke** [14] presented a general methodology for the derivation of a large number of hysteresis models for any structural system, including

multiple dimensions. **Erdem *et al.*** [15] report on experimental and analytical studies of strengthened RC frames and **Chuang *et al.*** [16] present their work on the retrofitting of unreinforced masonry using cables. **Leon *et al.*** [17] investigate and model the seismic performance of partially-restrained steel frames and **Decanini *et al.*** [18] report on the behaviour and modelling of masonry-infilled reinforced concrete frames.

Alternative reinforcement and concrete matrices were also presented. For example, **Canbolat *et al.*** [19] discuss their investigation on the use of fibres in precast, coupling beams for shear walls and **Paultre *et al.*** [20] provide recommendations for including high strength concrete in the Canadian standards.

5. Lifeline Systems

There is a significant increase in the development of more rational (versus empirical) analysis and design methodologies for underground lines, especially the study of connections and interaction phenomena for storage tanks.

6. Social and Economic Issues and Directions for the Future

Case studies on the development of strategies for less-developed countries are a major concern, especially the development of indices for decision-making given competing interests and limited resources.

The directions for the future are mainly along the trajectories defined and implied in the major code revisions since 1994 and recommendations such as SEAOC Vision 2000 (3):

(a) The refinement of the techniques of the performance-based, design philosophy including extension to multiple dimensions.

(b) Refinement of the displacement-based, design approach and (possibly the introduction of a comprehensive framework for energy-based design).

(c) A significant increase in the development of probabilistic methods but with the emphasis on design aids developed from parametric studies.

(d) The increase of more refined rational methods vs. empirical methods especially for lifeline systems.

(e) New supplemental damping and base isolation devices and methods for effective use.

(f) Refinement of design methods using geologic and geotechnical information.

(g) New hybrid and mixed material systems and their experimental characterisation.

(h) The development of more global and networked object-oriented systems for the integration of the overall EE effort.

7. Implications and Recommendations for Caribbean EE Research and Practice

7.1 Caribbean Research

7.1.1 Implications

Given the aforementioned trends, the following summarises the main implications for professions research in the Caribbean.

Pure Research

- The increased use and development of computer software to act as simulators of relevant phenomena suggest that significant contributions can be developed in the Caribbean since the required tools are relatively inexpensive (e.g., programmes such as DRAIN, IDARC, ADINA; compilers for software development; high-level maths tools such as MATHEMATICA, etc). The idea here is that with such tools, parametric studies can be undertaken to develop analysis and design procedures for a wide range of problem types. A large number of the papers presented in the structural engineering categories of the conference

were based on this approach. Software modules developed in the Caribbean can be tailored to expand the scope of the existing advanced software packages via collaborative efforts with the universities and institutions that develop them. Ideally, new mathematical models can be derived to drive the computational models especially since the extension of existing approaches to multiple dimensions is still in its infancy.

- The increased trend towards the refinement of the performance-based design paradigm fuels the invention of new systems, hence in this field pure and development research coincide. These systems, which may include passive control devices must be thoroughly tested for performance modelling. The paradigm shift from prescriptive to performance-based design implies that even the traditional prescriptive systems and sub-assemblages of structural concrete, steel, masonry and timber must be quantitatively re-categorised in terms of performance using more comprehensive models such as dynamic constitutive relations or hysteresis models. Given the conference presentations, this requirement is less than 30% complete. It is noteworthy that in this area, pressing issues of local interest can be appropriately resolved (e.g., the use of 100 mm masonry for seismic resistant, load-bearing walls; practical partially-restrained moment connections in the minor axis for structural steel members).

- The increased role of geological mechanisms for deriving design spectra, etc., implies that studies are needed of the region, and reassessment of risk to critical facilities. Given the lack of real data for events in excess of Richter magnitude 5.0 in the Caribbean, a methodology for the use of artificial accelerograms for providing a more statistically meaningful database is urgently needed.

Developmental Research

- Software can be developed for international markets. This is particularly feasible now since the time lag from procedure-definition, which is the end-result of conferences such as the 13WCEE and the availability of the software required by the professional design community is about three years. These need not be entire packages but can be "objects" for plug-in.

- The retrofit market is very large internationally and regionally. The development of more effective solutions, especially towards mitigation of seismic risk to critical facilities, is of extreme importance.

7.1.2 Recommendations

Pure Research

- Acquire the required tools for software development, and the already established but evolving advanced packages and perform parametric studies of the emerging issues.

- Develop new systems for earthquake resistance with and without the use of passive controls, and targeted for both new structures and the retrofit of existing structures. In terms of accepted test methods for structures in EE, The University of the West Indies Structures Lab can at present perform pseudo-static testing but this should be expanded to include pseudo-dynamic testing and maybe a simple (i.e., single-degree-of-freedom) frame-based shake-table. As discussed above, such studies can simultaneously satisfy the criteria of developmental research as well.

- More comprehensive investigation of the geological mechanisms and subsequent studies relevant to risk, design spectra, etc., should be undertaken locally and regionally.

Developmental Research

- Develop software components for use by the design community. Software for the earthquake-resistant design of basic elements is still lacking even internationally.

- This is the same as the aforementioned Item 2 for "Pure Research" – develop new retrofit technologies for regional and international use. Of particular significance is that The University of the West Indies can serve as a specialist centre for the seismic evaluation of existing facilities (e.g., of the energy and transportation sectors), and the preparation of retrofit measures. This possibility exists because the procedures of seismic evaluation of existing structures are much more complex than those of the design of new facilities.

7.2 Caribbean EE Practice

7.2.1 Implications

A summary of the implications of the 13WCEE for the Caribbean Practice of EE is as follows:

(1) Even before the conference, the major revisions of the 1990s to the codes used to design facilities in the Caribbean implied the need for a large re-training and re-tooling exercise for the region's professionals. The conference has indicated that the gap has in fact widened since procedures considered the domain of specialists five years ago (e.g., multi-dimensional modal analysis), are now being recommended as standard practice for the non-specialist. The growth rate of this gap is also increasing. Notwithstanding the inability to capitalise on the improvements in terms of greater safety and possible reduced cost, international lending agencies typically stipulate that regional facilities they are fimding be designed in accordance with the most recent codes. Yet our professionals are not familiar with these codes. Also, current plans for the revision of regional codes such as CUBiC are based on the new codes such as the IBC 2003.

(2) The conference noted that even in this technologically-advanced age, there are significant lessons to learn from recent earthquakes. One of the areas of improved understanding is the actual risk and risk distribution versus those derived from theory. The new approaches make it even more alarming that no comprehensive risk assessment and mitigation strategy has been undertaken for the Caribbean. A comprehensive approach will be in terms of the probability of damage to the economy, loss of human and natural resources, downtime estimates, and economic loss and recovery estimates. With such information, governmental agencies can plan effective mitigation strategies based on meaningful data and cost estimates. We are especially challenged by the dangerous belief held by many administrators and the populace in general that the region's risk is small.

7.2.2 Recommendations

- The University of the West Indies should implement a training programme for professionals that would enable the participant to have a firm and practical grasp of the requirements of the most recent codes. The initial stages for the development of such a programme is in progress — a draft programme and time-and-cost estimates have been prepared by the Department of Civil and Environmental Engineering, UWI.

- A thorough risk assessment and mitigation study for the region should be undertaken. This would be a multi-disciplinary effort with inter-governmental support and participation by specialists.

Concluding Remarks

The rate of development of EE and the size of the basic required skills-set have increased. With respect to the recommendations in terms of research agendas, a programme has been very briefly outlined that represents roughly 100 to 300 man-years of work required. This implies the need to establish a team for the medium-to-long-term (i.e., 10 to 20 years) implementation of such an effort. The new MSc Civil Engineering programme at the University of the West Indies should provide students needed for the research work. With respect to the recommendations for the Caribbean as a whole, the gap between what we know and need to know for optimally safe and economical design is unacceptable, as is our level of preparedness in the event of a significant earthquake. Addressing the latter will require roughly 50 to 80 man-years of multidisciplinary and inter-governmental effort.

The gap between where we are and need to be has widened to such an extent that even the standard language of discourse in earthquake engineering worldwide is unfamiliar to Caribbean engineers. It is hoped that at least some the aforesaid recommendations will be adopted for effectively addressing these concerns.

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