



CCEDDS-1

1st Canadian Conference on Effective Design of Structures

Transferring Research Into Practice

Program and Abstracts

McMaster University Centre for Effective Design of Structures
McMaster University
Hamilton, Ontario, Canada
July 10-13, 2005

CCEDS-1 2005 ORGANIZATION

The 1st Canadian Conference on Effective Design of Structures is being held at McMaster University, which is located in Hamilton, Ontario, Canada. The conference will run from July 10 – 13, 2005. The objectives of this conference are two-fold: to provide both a Canadian and International forum for communicating recent and projected advances in the field of structural engineering and to provide a forum for information exchange among delegates from the design profession, the construction industry, research organizations and academia. The theme of the conference is *Transferring Research into Practice*. The organizers hope to provide attendees with the unique opportunity to learn about state-of-the-art technologies in the fields of analysis, investigation and remediation of structures; masonry materials and building envelope; seismic design and retrofit of structures, and new and under-utilized materials and, subsequently, how these technologies are transferred into practice.

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CCEDS-1 2005 Program

Sunday, July 10, 2005

Time	Event	Location
5:00 PM – 9:00 PM	Registration	Mary Keyes Residence McMaster University
6:00 PM - 8:30 PM	Opening Reception	University Club McMaster University

Monday, July 11, 2005

Time				
8:00 AM - 10:00 AM	Registration MUSC Lounge			
8:15 AM - 8:20 AM	Welcoming Address			MUSC 319
8:20 AM - 9:10 AM	Chair: Luigia Binda Selective Rehabilitation to Enhance Seismic Performance of Masonry Buildings Dan Abrams*			MUSC 319
9:10 AM - 10:00 AM	Modernized Design of Masonry: Using Masonry's Strengths Effectively Robert Drysdale*			MUSC 319
10:00 AM - 10:30 AM	Coffee Break MUSC Lounge/Terrace			
	MUSC 309	MUSC 314	MUSC 315	MUSC 308
	Analysis, Investigation and Remediation of Structures I Chair: Mike Tait	Seismic Design and Retrofit of Structures I Chair: Ahmad Hamid	New and Under-Utilized Materials I Chair: Dieter Stolle	
10:30 AM - 11:00 AM	Rectangular Stress Block for High-Strength Concrete - A Comparative Study - T. Ozbakkaloglu and M. Saatcioglu	Application of a Damage Model to the Study of the Long Term Behaviour of Ancient Towers A. Anzani, L. Binda and A. Taliervo	The Influence of Contaminants in Recycled Concrete Aggregate on the Fresh and Hardened Properties of Concrete Chi-Sun Poon and Dixon Chan	
11:00 AM - 11:30 AM	Effective Shear Design of Large, Lightly Reinforced Concrete Beams and One-Way Slabs E.G. Sherwood, E.C. Bentz and M.P. Collins	Seismic Vulnerability Overview of Historical Masonry Churches in Europe P.B. Lourenço and D.V. Oliveira	New accelerated test method for compressed earth blocks A.G. Kerali	
11:30 AM - 12:00 PM	A Simplified Procedure to Predict the Force-Displacement Behavior of Concrete Coupling Beams R.A. Hindi and M.A. Hassan	Determination of Design Loads for the Seismic Retrofit of the Victoria Memorial Museum T.N. Stevens, D.J. Carson and J. Humar	The Influence of Self-Cementing Properties of Fine Recycled Concrete Aggregates on the Characteristics of Road Sub-base Materials Chi-Sun Poon, X. C. Qiao, and Dixon Chan	

* Keynote Address

Monday, July 11, 2005

12:00 PM - 1:00 PM	Lunch MUSC Terrace			
12:30 PM - 2:00 PM	Registration MUSC Lounge			
Time	MUSC 309	MUSC 314	MUSC 315	MUSC 308
	Masonry Materials and Building Envelope I Chair: Beatriz Martin-Pérez	Seismic Design and Retrofit of Structures II Chair: Jag Humar	New and Under-Utilized Materials II Chair: Paul Smeltzer	Building Envelope Workshop I
1:00 PM - 1:30 PM	Feasibility of Using Recycled Fine Aggregates in Concrete Masonry Blocks Chi-Sun Poon and Dixon Chan	Design of FRP Reinforced Concrete Structures for Seismic Effects M. K. Sharbatdar and M. Saatcioglu	System Design of Modern Light Wood Frame Buildings Y. H. Chui and I. Smith	Eric Burnett, Samir Chidiac, John Straube 1:00 PM - 2:30 PM
1:30 PM - 2:00 PM	Stabilized Building Blocks incorporating Volcanic Ash and Finely Ground Natural Lime K. M. A. Hossain and M. Lachemi	Upgrading T-Beams Subjected to Combined Torsion and Shear Using CFRP A. Deifalla and A. Ghobarah	Effective Utilization of Structural Timber using the Novel Tube Connection A.J.M. Leijten	
2:00 PM - 2:30 PM	Effects of the Addition of Waste Glass on the Compressive Strength of Fired Clay Brick L.M. Federico and S.E. Chidiac	Reliability of the Strain Compatibility-Based Model for Estimating the Gain in Flexural Strength of CFRP-Retrofitted Girders E.Y. Sayed-Ahmed, A.H. Riad and N.G. Shrive	Cold-Formed Steel Joists with Reinforced Web Openings M. Y. Ng, S. R. Fox, and K.S. Sivakumaran	
2:30 PM - 3:00 PM	Coffee Break MUSC Lounge/Terrace			
	Masonry Materials and Building Envelope II Chair: Murat Saatcioglu	Analysis, Investigation and Remediation of Structures II Chair: Robert Drysdale		Building Envelope Workshop II
3:00 PM - 3:30 PM	Shear-Compression Interaction in Composite URM-FRP Walls Ahmad A. Hamid, Wael W. El-Dakhkhni, Zeyad H.R. Hakam and Mohamed Elgaaly	Diagnosis of Premature Defects and Deficiencies Associated with Building Process Oversights A.G. Kerali		Eric Burnett, Samir Chidiac, John Straube 3:00 PM - 4:30 PM
3:30 PM - 4:00 PM	A Model for Confinement by means of Fiber Reinforced Polymers E.Vintzileou	Design and Remediation of Overhang Drip Edges R.H. Fletcher		
6:00 PM – 8:00 PM	Ice Breaker MUSC Atrium/McMaster Museum of Art			

Tuesday, July 12, 2005

Time				
8:00 AM - 10:00 AM	Registration MUSC Lounge			
8:20 AM - 9:10 AM	Chair: Saeed Mirza Seismic Rehabilitation of Nonductile Structures Murat Saatcioglu*			MUSC 319
9:10 AM - 10:00 AM	Seismic Retrofit of Steel Structures Michel Bruneau*			MUSC 319
10:00 AM - 10:30 AM	Coffee Break MUSC Lounge/Terrace			
	MUSC 309	MUSC 314	MUSC 315	MUSC 308
	Analysis, Investigation and Remediation of Structures III Chair: Samir Chidiac	Seismic Design and Retrofit of Structures III Chair: Ashraf El-Damatty	Masonry Materials and Building Envelope III Chair: Anna Anzani	
10:30 AM - 11:00 AM	Finite Element Analysis of Corrosion-Induced Cracking, Spalling and Delamination of RC Bridge Decks K. Zhou, B. Martín-Pérez and Z. Lounis	A Parametric Study on the Seismic Behavior of Liquid Containing Structures Based on ACI 350 Code Reza Kianoush, Ahmed Hafez, and Hassan Mirzabozorg	Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing L. Binda, A. Borri, M. Corradi and C. Tedeschi	
11:00 AM - 11:30 AM	Design of Reinforced Concrete Elements for Durability against Corrosion C. Ji, S. Jefremczuk and M.S. Mirza	A Preliminary Study of a Tuned Liquid Damper with Smart Screens Marcus Casson and Michael Tait	Hydration of the Condensed Silica Fume in Presence of Lime and Cements M.N Oudjit, K. Arroudj and A. Bali	
11:30 AM - 12:00 PM	Modelling the Effects of Variations in pH on the Free Chloride Concentration in Concrete O.B. Isgor and A.G. Razaqpur	Floor Response Spectra for Reinforced Concrete Frame Buildings in Canada S. Foo, N. Naumoski, T. Ozbakkaloglu and M. Saatcioglu	The Use of Bearing Wedges to Eliminate the Influence of Construction Gaps in Steel Frames Infilled with CASIEL Walls B.M. Ng'andu, A.T. Vermeltoort, and D.R.W. Martens	
12:00 PM - 1:00 PM	Lunch MUSC Terrace			
12:30 PM - 2:00 PM	Registration MUSC Lounge			

* Keynote Address

Tuesday, July 12, 2005

Time	MUSC 309	MUSC 314	MUSC 315	MUSC 308
	Analysis, Investigation & Remediation of Structures IV Chair: Steve Fox		Precast Concrete Drainage Products I	Earthquake Engineering Workshop I
1:00 PM - 1:30 PM	Development of a Numerical Tool to Improve the Design of Transmission Towers by Accounting for Downburst Loads A.Y. Shehata and A.A. El Damatty		Research Suggests Conservative Design of Concrete Box Culverts Paul Smeltzer and Evan Bentz	John Adams, Arthur Heidebrecht, Jag Humar, Murat Saatcioglu, and Cathy Taraschuk 1:00 PM - 2:30 PM
1:30 PM - 2:00 PM	Effective Design of Stiffeners on Industrial Ducts J.D. Udall, B. Halabieh, S.E. Chidiac		Detection of Depth of Surface-Breaking Cracks in Concrete Pipes Y. Yang, G. Cascante and M. A. Polak	
2:00 PM - 2:30 PM	Moment Resistance of Laterally Unsupported Steel I-beams: A Proposed Equation for LRFD Approach E.Y. Sayed-Ahmed and R.E. Loov		Current Issues with Dry Cast Concrete Containing Blast Furnace Slag S.E.Chidiac, D.K.Panesar, P.Smeltzer and E.Kling	
2:30 PM - 3:00 PM	Coffee Break MUSC Lounge/Terrace			
	Masonry Materials and Building Envelope IV Chair: Chedo Sobot		Precast Concrete Drainage Products II	Earthquake Engineering Workshop II
3:00 PM - 3:30 PM	Further Validation of The Inverse Method for Predicting Air Flow in Buildings R.C. Richman and K.D. Pressnail		Field Performance of a Concrete Pipe Culvert Installed Using Standard Installations P.D. Smeltzer and L. Daigle	John Adams, Arthur Heidebrecht, Jag Humar, Murat Saatcioglu, and Cathy Taraschuk 3:00 PM - 4:30 PM
3:30 PM - 4:00 PM	The Current Problem Concerning Energy Saving in Buildings and Houses: Analyses, Solutions and a Fast Way for Transferring Research into Practice E. Litovsky, J. Mar, and J. Kleiman		Indirect Design Method – Marston Spangler Method of Estimating Loads on Buried Pipe Paul Smeltzer	
4:00 PM - 4:30 PM	Assessing Sustainability in the Construction Industry C.A. Wall, T.R. Harris, P. Couture, A. St. Michel		Effect of Metal Oxide Coating on Generation of Sulfide in Concrete Sewer Pipes E. Hewayde, G. Nakhla, and E. Allouche	
6:00 PM – 11:00 PM	Banquet Dinner Grand Central Ballroom, Liuna Station, Hamilton			

Wednesday, July 13, 2005

Time				
8:00 AM - 10:00 AM	Registration MUSC Lounge			
8:30 AM - 9:30 AM	Chair: Robert Drysdale A Framework for Durability Design of Infrastructure Saeed Mirza*			MUSC 319
9:30 AM - 10:00 AM	Engineering the Future: Adapting Civil Infrastructure in a Changing Climate Michael Mortimer**			MUSC 319
10:00 AM - 10:30 AM	Coffee Break MUSC Lounge/Terrace			
	MUSC 309	MUSC 314	MUSC 315	MUSC 308
	Masonry Materials and Building Envelope V Chair: David Stubbs	Seismic Design and Retrofit of Structures IV Chair: Riyadh Hindi	Analysis, Investigation and Remediation of Structures V Chair: Dieter Stolle	
10:30 AM - 11:00 AM	Freeze-thaw Durability of Concrete Masonry Products H. Zibara and S.E. Chidiac	Dynamic Behaviour of the Confederation Bridge due to Seismic Loads L. Lin, N. Naumoski, S. Foo and M. Saatcioglu	Development of Ultra-Lightweight Concrete and Concrete Products Caijun Shi	
11:00 AM - 11:30 AM	Lightweight Concrete with Pumice Aggregate: Mix Design and Fire Resistance K. M. A. Hossain and M. Lachemi	Explicit Finite Element Approach for Effective Collapse Simulation of Steel Box Bridge Piers under Multi-directional Earthquake Loading H. H. Mohammed	Recommendation of Response Modification Factor (R) for Concrete Shaft Staging Elevated Tanks M. Masoudi and M. Ghafory-Ashtiany	
11:30 AM - 12:00 PM	Development of a Finite Element Program for Three-Dimensional Nonlinear Analysis of Reinforced Masonry Buildings A.A. El Damatty, A.A. Hamid and R.G Drysdale	3-D Nonlinear Finite Element Modeling of Cable-stayed Bridge Moe M.S. Cheung, King-Sze Chan and Cheng-Yu Yang	Recommendation of Response Modification Factor (R) for Concrete Frame Staging Elevated Tanks M. Masoudi and M. Ghafory-Ashtiany	
1:00 PM - 4:00 PM	Tour of Applied Dynamics Lab (ADL) 1:00 PM - 2:30 PM			Masonry Workshop Robert Drysdale and Dave Stubbs

* Keynote Address

** Invited Speaker

Monday, July 11, 8:20 AM - 9:10 AM, room MUSC 319

Selective Rehabilitation to Enhance Seismic Performance of Masonry Buildings

D.P. Abrams

Donald B. Willett Professor of Engineering, University of Illinois at Urbana-Champaign, 2118 Newmark Civil Engineering Laboratory, 205 N. Mathews, Urbana, Illinois, USA, 61801, d-abrams@uiuc.edu

Abstract

Effective seismic rehabilitation of existing, unreinforced masonry buildings is discussed in terms of new performance-based design concepts. This paper illustrates how setting displacement capacities to exceed displacement demands for a particular intensity of earthquake and performance objective can result in effective seismic rehabilitation of this form of construction. As an outcome, not only is structural safety ensured, but also performance, aesthetics, cost and practicality of reconstruction may be enhanced. Reference is made to supporting research on seismic performance of rehabilitated unreinforced masonry components and building systems, and recommendations for further research are given.

Keywords: buildings, earthquakes, performance-based design, rehabilitation, rocking, seismic, sliding, unreinforced masonry.

Monday, July 11, 9:10 AM - 10:00 AM, room MUSC 319

Modernized Design of Masonry: Using Masonry's Strengths Effectively

R.G. Drysdale

Professor and Martini, Mascarini and George Chair in Masonry Design, Director, Centre for Effective Design of Structures, Dept. of Civil Engineering, McMaster University, Hamilton, ON, L8S 4L7, Canada, drysdale@mcmaster.ca

Abstract

In my more than thirty years of involvement with masonry research and teaching and working with the masonry industry, masonry has been perpetually at the cross roads between assuming a diminishing role as a construction material versus making large strides forward as a modernized building material. The perception that the manpower intensive nature of masonry construction has or will make it uncompetitive as a construction material has been repeatedly disproven. Despite this, masonry has faced and does face continuing challenges, which, at least, hamper making the large strides forward mentioned above.

This paper contains a discussion of educational and research issues that must be addressed to remove many of these road blocks to more widespread use of masonry. On the positive side, recent research and incorporation of the knowledge gained in recently published codes and standards places masonry on a more even playing field with competing construction materials and, in a few cases, offers significant advantages for the use of masonry. Specific examples are provided on how masonry's inherent strengths can be used effectively in design. This modernized design of masonry, the necessary design tools, and the necessary proactive support of the masonry industry are discussed as key features to an expanding role for masonry in construction.

Monday, July 11, 10:30 AM - 12:00 PM

Analysis, Investigation and Remediation of Structures I, room MUSC 309

Rectangular Stress Block for High-Strength Concrete - A Comparative Study -

T. Ozbakkaloglu¹ and M. Saatcioglu²

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Abstract

Structural use of high-strength concrete (HSC) has increased in recent years. Concrete strengths of up to 130 MPa are currently being used especially in the columns of building and bridge structures. HSC offers superior performance and economy, and provides an attractive alternative to other construction materials.

Designing HSC structures requires a representative stress block that reflects concrete stress-strain characteristics reasonably accurately. The stress-strain relationship of concrete varies with strength, changing from approximately a second order parabola for normal-strength concretes to almost a triangular variation for high-strength concretes, with a steep initial ascending and descending slopes. The rectangular stress block specified in the ACI 318-05 Building Code does not recognize these changes in stress-strain relationships, overestimating column capacity, resulting in unsafe designs. The CSA A23.3-1994 Standard does incorporate higher strength effects, but produces over-conservative designs under various circumstances. Therefore a new rectangular stress block was developed by the authors, and was verified extensively against available experimental data.

This paper provides a review of available rectangular stress blocks for HSC, and presents comparisons with a large volume of experimental data. The evaluation of data is presented for different ranges of concrete strength and axial load levels, as these two parameters affect the strength computations significantly. In addition to the model proposed by the authors, those recommended by the CSA A23.3-1994, ACI 318-05 and New Zealand Codes are also included. The comparisons are presented with due considerations given to the level of accuracy, rationale for background, as well as safety and conservatism attained.

Keywords: concrete, columns, flexural strength, high-strength concrete (HSC), rectangular stress block.

Effective Shear Design of Large, Lightly Reinforced Concrete Beams and One-Way Slabs

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Abstract

Both the Canadian (CSA) and American (ACI) design codes for reinforced concrete have been updated and reissued in 2005. While the CSA method for shear design has been modified based on ongoing research, the ACI method continues to use traditional equations introduced over 40 years ago. As such, there is concern that the ACI method may be unconservative for large, lightly reinforced concrete beams and one-way slabs. The purpose of this paper is to report on an experimental program conducted at the University of Toronto designed to investigate the effectiveness of the ACI and CSA shear design methods for these types of elements. It was found that the ACI method is unconservative when applied to large beams without stirrups. The CSA method, however, produces safe and effective designs.

Keywords: shear, design, reinforced concrete, size effect

(continued) Monday, July 11, 10:30 AM - 12:00 PM

(continued) Analysis, Investigation and Remediation of Structures I, room MUSC 309

A Simplified Procedure to Predict the Force-Displacement Behavior of Concrete Coupling Beams

R.A. Hindi¹ and M.A. Hassan²

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²Civil Engineer, Illinois Department of Transportation, Peoria, IL, USA

Abstract

This paper presents a simplified procedure to predict the monotonic behavior of diagonally reinforced coupling beams of shear walls. The procedure yields a trilinear monotonic force-displacement response up to failure. The proposed simplified procedure can be easily utilized by design engineers. The procedure assumes all load is resisted by diagonal tension and compression. The diagonal compression is carried by the diagonal reinforcement and the concrete core, while the diagonal tension is carried only by the diagonal reinforcement alone. Either rupture of the diagonal reinforcement or crushing of the concrete core defines the end point of the behavior (failure) of the coupling beam. The proposed trilinear approximation is applied and compared to 13 specimens that were experimentally tested by other investigators. The specimens vary in terms of dimensions, reinforcement and material properties.

Keywords: concrete; coupling beam; diagonal reinforcement; monotonic behavior.

Seismic Design and Retrofit of Structures I, room MUSC 314

Application of a Damage Model to the Study of the Long Term Behaviour of Ancient Towers

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Abstract

A further step toward the understanding of the mechanical behaviour of ancient masonry under persistent loading is taken, thanks to a new experimental research performed on the masonry of the collapsed medieval tower of Pavia, subjected to pseudo-creep tests. The laboratory results are interpreted with the help of a visco-elastic rheological model, including damage variables, for a subsequent application to construction analysis.

Keywords: ancient masonry, creep, viscoelasticity, damage.

(continued) Monday, July 11, 10:30 AM - 12:00 PM

(continued) Seismic Design and Retrofit of Structures I, room MUSC 314

Seismic Vulnerability Overview of Historical Masonry Churches in Europe

P.B. Lourenço¹ and D.V. Oliveira²

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Abstract

This paper presents a contribution for the safety assessment of historical masonry churches located in earthquake prone areas. Six different simplified safety indexes (three in-plane and three out-of-plane) are analyzed, taking into account a large sample of forty-four European churches. The sample of buildings has been organized according to the seismic hazard. All in-plane indexes are compared with proposed thresholds, in order to detect cases in serious risk and to define priority of studies. These indexes do not present a clear tendency with respect to seismicity, though a slightly trend can be established. Even for low seismicity areas, in-plane indexes are often violated. Based on the results achieved, a proposal for the usage of the simplified indexes is made. The analysis of the out-of-plane indexes illustrates that a logical common trend with respect to seismicity can be found, which points out the possibility of defining threshold criteria, as used for the in-plane indexes. The results indicate that valuable information can be obtained from simplified methods, with respect to performing a first screening and to prioritizing further deeper investigations.

Keywords: seismic vulnerability, historical masonry, safety assessment

Determination of Design Loads for the Seismic Retrofit of the Victoria Memorial Museum

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Abstract

The Victoria Memorial Museum (VMM), located in Ottawa, Ontario, is a heavy stone masonry structure that was built between 1905 and 1911 and is considered one of Canada's most important heritage buildings. As part of a major renovation to the museum, a seismic retrofit of the existing building was undertaken. A magnitude M6.0 earthquake is considered representative for the Ottawa region. Due to the impending changes of the National Building Code of Canada (NBCC), and the sensitive geotechnical conditions of the building site, extensive analysis was carried out to determine the seismic loads to be used for the retrofit. The equivalent static base shear using the 1995 NBCC is 0.126W. A review of the draft 2005 NBCC indicates that earthquake design forces for the VMM increase by more than 50% (0.184W).

A site-specific seismic design response spectrum at ground level representative of an Ottawa area earthquake for the VMM was developed¹. A study of the propagation of the seismic motion from bedrock to ground level using ProShake and the underlying soil characteristics of the site resulted in earthquake time histories and response spectra at ground level. A smooth site specific spectrum representing the mean of the spectra produced was developed. The smoothed site specific spectrum indicates that the earthquake forces in the period range of interest for the VMM are greater than the forces prescribed in the 1995 NBCC. The 2005 NBCC UHS for a class D site in Ottawa generally envelopes the smoothed site specific spectrum.

Keywords: ETABS, heritage, masonry, ProShake, seismic, spectrum

(continued) Monday, July 11, 10:30 AM - 12:00 PM

New and Under-Utilized Materials I, room MUSC 315

The Influence of Contaminants in Recycled Concrete Aggregate on the Fresh and Hardened Properties of Concrete

Chi-Sun Poon¹ and Dixon Chan²

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Abstract

The use of recycled concrete aggregate in concrete has been successfully implemented and is gaining wider acceptance. In Hong Kong, 100% coarse recycled concrete aggregate (RCA) may be used in the production of Grade 20 concrete. However, the allowable contamination level of foreign materials (e.g. crushed clay brick, crushed ceramic tile etc) in the recycled concrete aggregate is very low (<1%) in the current specifications due to stringent quality control standards that are usually adopted from specifications for virgin materials. This study employed crushed clay brick and crushed ceramic tile as the contaminants in the RCA. They were used to replace 15 and 25% by volume of the 10 mm RCA in preparing concrete mixes at a free water-to-binder (w/b) ratio of 0.55. The results indicated that the initial slump of the contaminated RCA concrete mixes was higher than that of the concrete prepared with 100% RCA. This was attributed to the relatively high amount of water that was required in the concrete mixes in order to compensate the high water absorbability of the contaminants. However, the contaminated RCA concrete mixtures exhibited a greater slump loss. Furthermore, the compressive strength and static modulus of elasticity of the contaminated RCA concrete were lower compared to those of concrete prepared with 100% RCA. Nevertheless, this study proved that it is feasible to produce Grade 20 concrete prepared with 100% coarse RCA as long as the crushed clay brick or crushed tile content in the 10 mm RCA does not exceed 25%.

Keywords: recycled concrete aggregate, contaminants, crushed clay brick, and crushed tile

New accelerated test method for compressed earth blocks

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Abstract

Compressed earth blocks (CEB) are now recognized as important walling units for low-cost dwellings in developing countries. Unfortunately, their durability under in-service conditions in the humid tropics is causing concern. Premature deterioration typified by surface erosion, mass loss, pitting, roughening, scouring, cracking, and crazing are rampant. Current predictive test methods simulating the main causes of surface deterioration (wetting, abrasion, and drying) are inadequate and misleading. Yet good surfaces are required if blocks are to remain durable for their service duration. A new test method is therefore required to evaluate the quality of block surfaces during and after curing. This paper documents some exploratory and promising results obtained by using the slake-durability test (SDT) method, originally developed for argillaceous rocks. During the test, surface erosion leading to mass loss of between 1 and 50% were recorded within a period of only 10 minutes. The paper concludes that use of the SDT method is not only fast and relevant, but is also robust and appropriate. The method is also reliable, controllable, and repeatable. Moreover, blocks of any service and storage record can be tested, and only those found to be dimensionally stable, and by implication durable, can be produced. Owing to the rapid acceleration of surface erosion, the method is now being recommended as a quick predictive surface and quality test for CEBs and other like materials.

Keywords: compressed earth blocks, slake-durability test, durability, deterioration.

(continued) Monday, July 11, 10:30 AM - 12:00 PM

(continued) New and Under-Utilized Materials I, room MUSC 315

The Influence of Self-Cementing Properties of Fine Recycled Concrete Aggregates on the Characteristics of Road Sub-base Materials

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Abstract

The use of coarse recycled concrete aggregate (RCA) in conjunction with fine RCA as sub-base materials has been widely studied. Although research results indicated that it was feasible to employ both coarse and fine RCAs as granular sub-base, the influence of the un-hydrated cement in the adhered mortar of the RCA on the properties of the sub-base materials has not been thoroughly studied. Generally, it is known that the strength of the sub-base materials prepared with RCA increases over time. However, this mechanism, known as the self-cementing properties, is not well understood and is believed to be governed by the properties of the fine portion of the RCA (< 5 mm). This paper presents an investigation on the cause of the self-cementing properties by measuring x-ray diffraction patterns, pH values, compressive strength and permeability of various size fractions of the fine RCA. Their influence on the overall sub-base materials was determined. The results indicated that the size fractions of < 150 mm and 0.3-0.6 mm were most likely to be the principal cause of the self-cementing properties of the fine fractions of RCA. However, its effects on the properties of the overall RCA sub-base materials were minimal.

Keywords: recycled concrete aggregate; sub-base; self-cementing properties

Monday, July 11, 1:00 PM - 2:30 PM

Masonry Materials and Building Envelope I, room MUSC 309

Feasibility of Using Recycled Fine Aggregates in Concrete Masonry Blocks

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Abstract

This study investigated the feasibility of using recycled aggregates derived from construction and demolition (C&D) waste streams in concrete masonry blocks for non-loadbearing applications. The recycled aggregates used in this study included recycled concrete aggregate, crushed clay brick and crushed ceramic tile. The recycled materials were crushed to <5 mm size aggregates prior to using as the fine aggregates in the experiment. The density, compressive strength and drying shrinkage of the blocks at different mixing ratios were determined. Since the aggregates derived from C&D waste were more porous and had a high water absorption value, the concrete blocks produced were expected to have a high drying shrinkage value. Therefore, a technique for reducing the drying shrinkage of the blocks was proposed by incorporating crushed waste glass in the mix design of the blocks since the waste glass particles had a negligible water absorption value. The results indicated that the drying shrinkage gradually decreased as the crushed waste glass content increased while the incorporation of crushed waste glass did not cause an adverse effect on the compressive strength of the masonry blocks.

Keywords: recycled concrete aggregate, crushed clay brick, crushed tile, crushed waste glass, masonry blocks

(continued) Monday, July 11, 1:00 PM - 2:30 PM

(continued) Masonry Materials and Building Envelope I, room MUSC 309

Stabilized Building Blocks incorporating Volcanic Ash and Finely Ground Natural Lime

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Abstract

Stabilized blocks are extremely useful building materials for developing countries around the world. These blocks can be made of locally available soils and stabilizers to build low-cost durable houses. With careful selection of materials, such blocks can be produced with strength and durability characteristics comparable to other commonly used masonry materials and have the appearance of fired clay bricks. This paper presents the results of an investigation on the development of stabilized building blocks using Papua New Guinea (PNG) soils collected from various parts of the country and incorporating different locally available natural and industrial materials as stabilizers such as: Portland cement, lime powder, volcanic ash and their combinations. Lime is available as natural deposits in huge quantities in various parts of Papua New Guinea while volcanic ash is abundant due to volcanic activities in volcanic areas of the country. The use of these two natural resources as stabilizers in stabilized building block production is important especially for the local population. It can provide low-cost housing and lead to the reduction of natural hazards in volcanic areas where deposited volcanic ash and its removal are cause of concerns. The performance characteristics of stabilized blocks with different stabilizers are compared and presented. The strength and durability characteristics of developed stabilized blocks are also compared with well known building blocks from other countries including adobe bricks in Mexico.

Keywords: stabilized soil blocks, volcanic ash, strength, durability, cement, lime

Effects of the Addition of Waste Glass on the Compressive Strength of Fired Clay Brick

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Abstract

Addition of waste glass to fired clay bricks has demonstrated the potential to increase compressive strength while improving production costs. Accordingly, a testing program was developed to further investigate the benefits of adding waste glass. The variables studied were the concentration of the waste glass, specifically 5%, 10% and 15% concentration of glass by mass, and the corresponding glass particle size. The particle size of the added waste glass was varied within two groupings, where particle sizes ranging from 0.3 to 0.15 mm were designated as "coarse", and 0.15 to 0.075 mm designated as "fine". Compressive strength was evaluated and the resulting values were compared with both the control specimens and data reported in the literature. The results reaffirmed trends of previous work in which increasing the percent concentration of waste glass lead to increased compressive strength well beyond the recommended minimum values for bricks used in exterior construction applications. Specimens containing fine glass particles yielded larger strength values in comparison to the coarse ones, with increasing concentrations of glass.

Keywords: brick, waste glass, compressive strength, clay, shale

(continued) Monday, July 11, 1:00 PM - 2:30 PM

Seismic Design and Retrofit of Structures II, room MUSC 314

Design of FRP Reinforced Concrete Structures for Seismic Effects

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Abstract

Fiber reinforced polymer (FRP) reinforcement, in the form of longitudinal bars and transverse grids is currently being developed for use in new building and bridge structures. However, FRP reinforcement shows linear stress-strain characteristics up to failure, without any ductility. This poses serious concerns about their applicability to earthquake resistant structures. Experimental research is currently conducted at the Structures Laboratory of the University of Ottawa to investigate the seismic performance of FRP reinforced concrete structural elements. Large scale columns and beams are being tested under simulated seismic loading. The results of selected tests are summarized in this paper, with the assessment of their significance from seismic performance perspective. Specimens representing part of a first storey building column between a footing and the point of inflection; and the portion of a beam between a column and the point of inflection, were tested under lateral deformation reversals. The members were reinforced with carbon FRP bars in the longitudinal direction, and carbon FRP grids in the transverse direction. Both the columns and the beams sustained a minimum of 2% to 3% lateral drift ratios, meeting seismic drift limitations of most building codes. Hysteretic relationships indicate progressive stiffness degradation due to concrete cracking, followed by inelasticity in columns due to gradual crushing of confined concrete. Test results indicate that FRP reinforced concrete elements exhibit reduced stiffness and softened response, when compared with conventional steel reinforced concrete elements, because of the lower elastic modulus of FRP bars. This may suggest reduced spectral values associated with longer vibration periods, as well as increased deformability, resulting in seismic resistant structures for which elastic design approach with sufficient deformability may be appropriate.

Keywords: concrete, confinement, ductility, earthquakes, FRP, fiber reinforced polymer bars, reinforced concrete, seismic resistant design, structures.

UPGRADING T-BEAMS SUBJECTED TO COMBINED TORSION AND SHEAR USING CFRP

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Abstract

Repair and rehabilitation of concrete structures is important in many cases including for example, increase in service loads due to a change in the usage of the building, or in case of degradation problems because of exposure to aggressive environments. In addition, repair may be required in cases of design and/or construction errors. Externally bonded fibre reinforced polymer (FRP) laminates are becoming popular for the rehabilitation, repair, and retrofit of concrete structures. Torsion plays a vital role in the design of many structures, however strengthening for torsion has not received much attention. The little research reported to date has focused on the case of strengthening rectangular reinforced concrete (RC) beams subjected to pure torsion. However, since torsion is usually associated with moment and/or shear, studying the behaviour of strengthened RC beams under combined shear and torsion is a more realistic investigation.

This paper presents a review to the previous experimental investigation on torsion strengthening of concrete beams. In addition, the behaviour of carbon fibre reinforced polymers (CFRP) strengthened RC T-beams subjected to combined shear and torsion is explored. A test setup capable of simulating the case of combined shear and torsion is presented. Three half-scale beams, a control specimen and two strengthened beams were constructed and tested using a specially designed test setup. Two strengthening techniques using carbon fibre reinforced polymers CFRP were implemented. The effectiveness of the proposed strengthening techniques is discussed.

Keywords: beams, torsion, shear, rehabilitation, strengthening, repair, twist.

(continued) Monday, July 11, 1:00 PM - 2:30 PM

(continued) Seismic Design and Retrofit of Structures II, room MUSC 314

Reliability of the Strain Compatibility-Based Model for Estimating the Gain in Flexural Strength of CFRP-Retrofitted Girders

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Abstract

There has been increasing use of Advanced Composite Materials to strengthen reinforced concrete beams in the past few years. In this paper, flexural strengthening of certain precast bridge girders using Carbon Fibre Reinforced Polymers (CFRP) strips/sheets is presented. The experimental investigation was performed on full-scale girders from a dismantled bridge in Alberta (Canada). The mathematical models currently used to predict the flexural strength of FRP retrofitted girders were adopted for the retrofitted girders. Results of the experimental investigation were found not to be in full agreement with the mathematical models. The discrepancy is outlined and explained using a simple strut and tie model. Further investigation into the failure modes of CFRP retrofitted girders is presented through the testing of smaller size beams with soffit-bonded CFRP strips. The outcomes lead to the conclusion that reliance solely on the mathematical models currently used to estimate the flexural capacity of reinforced concrete girders retrofitted with bonded CFRP strips is open to question.

Keywords: bridges, CFRP strips, CFRP sheets, flexural strengthening, rehabilitation.

New and Under-Utilized Materials II, room MUSC 315

System Design of Modern Light Wood Frame Buildings

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Abstract

Light wood frame construction has provided safe, efficient and affordable shelter for Canadians for close to two centuries. Construction techniques and products have evolved from balloon construction to platform frame construction, and ultimately modern wood frame systems. A constant feature has been a high degree of structural redundancy, creating numerous load paths to distribute externally applied loads. Both structural and non-structural elements play major roles in transfer of loads to reaction points. The usual design approach is to conceptualise a building as made up of 2-dimensional structural elements such as roof trusses and shearwall panels; and floor joists, and then design each element separately. Certain effective load paths and much of load sharing between components are ignored for tractability and convenience.

Here results from projects undertaken at the University of New Brunswick are used to illustrate experimental and theoretical means of quantifying the difference between design predictions using conventional element-by-element analysis and 'real behaviour' of complete structural systems. The results clearly demonstrate that efficient engineering solutions for light wood frame buildings are only possible if a system design approach is employed.

Keywords: design, light-frame, load paths, floor performance, system effects, wood.

(continued) Monday, July 11, 1:00 PM - 2:30 PM

(continued) New and Under-Utilized Materials II, room MUSC 315

Effective Utilization of Structural Timber using the Novel Tube Connection

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Abstract

Timber connections with dowel type fasteners such as dowels or bolts generally face two main setbacks. The first is the appearance of unexpected cracks resulting in an unreliable strength and ductility. The second is the hole clearance, which results in unreliable stiffness and lack of immediate load take up especially in cases where the load sign changes. During the nineties of the last century a novel timber connection was developed at the Faculty of Civil Engineering TU-Delft, the Netherlands called the tube connection that solved both shortcomings. Cracks were prevented by gluing reinforcement onto the timber surface. The solid dowel type fastener was replaced by a steel tube to fit in oversized holes. After assembly the tube diameter was increased to obtain a tight fit without hole clearance without introducing new production techniques. The static as well as hysteresis properties were assessed. A high and reliable strength, stiffness capacity as well as a high ductility were observed. Structural design comparison of a two hinge frame showed that the application of the tube connection resulted in 40% of timber savings which clearly underlines the structural effectiveness of using this novel connection. Six timber structures have successfully been erected. It was demonstrated that the high performance tube connection is able to increase the structural efficiency of the material resulting a more competitive and cost effective design compared to the traditional use of dowel type connections.

Keywords: timber, connections, joints, reinforcement, dvw, tube.

Cold-Formed Steel Joists with Reinforced Web Openings

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Abstract

The floor joists of Cold-Formed Steel (CFS) structures often require large web openings. Reinforcement of such openings may mitigate the detrimental effects of such web openings. This paper is based on an experimental investigation which considered 203mm deep 14 gauge (thickness 1.91mm) galvanized lipped channel sections having circular, square, and rectangular openings, and two associated reinforcement schemes. The test specimens were simply supported, and were subjected to two equal point loads at equal distance from the supports. Two lipped channel sections with a length of 2743 mm were set face-to-face to form the test specimen. Based on these limited tests, it was determined that [a] tension zones of the web having a large opening need not be reinforced, [b] closely spaced screw fastening of reinforcements is essential, and [c] the reinforcements need to be as close as possible to the compression edges of the opening, in order to minimize crippling of these edges. Overall, it is evident that it is possible to establish cost-effective reinforcement schemes for CFS sections having large web openings.

Keywords: cold-formed steel, joists, web openings, reinforcements, experimental.

Monday, July 11, 1:00 PM - 4:30 PM, room MUSC 308

Building Envelope Workshop

Eric Burnett, Samir Chidiac, John Straube

This workshop treats the following subjects: Damage mechanisms for masonry, Moisture Sources and Sinks, Rain Control for Enclosures, Airflow Control, Diffusion Control, Thermal Control, and Examples of Good Buildings.

Monday, July 11, 3:00 PM - 4:00 PM

Masonry Materials and Building Envelope II, room MUSC 309

Shear-Compression Interaction in Composite URM-FRP Walls

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Abstract

An experimental investigation was conducted to study the in-plane behaviour of face shell mortar bedded unreinforced masonry (URM) wall assemblages retrofitted with fiber-reinforced polymer (FRP) laminates. Thirty-six URM assemblages were tested under different stress conditions present in masonry shear and infill walls. Tests included prisms loaded in compression with different bed joint orientation (on/off-axis compression), diagonal tension specimens, and under joint shear. The behaviour of each specimen type is discussed with emphasis on modes of failure, strength and deformation characteristics. Results showed that the application of FRP laminates on URM has a great influence on strength, post peak behaviour, as well as altering failure modes and maintaining the specimen integrity. The retrofitted compression prisms reached compressive strength of 1.62 to 5.64 times that of their unretrofitted counterparts depending on the bed joint orientation, and joint shear strength increased by eightfold using the FRP.

Keywords: composite masonry; concrete masonry; fiber reinforced plastics; retrofitting; seismic hazard; shear walls.

(continued) Monday, July 11, 3:00 PM - 4:00 PM

(continued) Masonry Materials and Building Envelope II, room MUSC 309

A Model for Confinement by means of Fiber Reinforced Polymers

E.Vintzileou

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Abstract

In this paper, an empirical model is presented allowing for prediction of the characteristics of concrete confined by means of FRPs. To this purpose, formulae similar to those adopted by Eurocode 2 (for confinement provided by closed hoops) are developed. A database, including the results of more than 80 experimental programs, was used to calibrate the model. The database comprises results obtained from tests on both unreinforced and reinforced specimens, cylindrical and prismatic, confined by FRP sheets or strips or wires with carbon or glass or aramid fibers. The model fits satisfactorily the experimental results, thus providing a useful tool for design of FRP applications aiming at confining concrete.

Keywords: concrete, confinement, fiber reinforced polymers (FRP).

Analysis, Investigation and Remediation of Structures II, room MUSC 314

Diagnosis of Premature Defects and Deficiencies Associated with Building Process Oversights

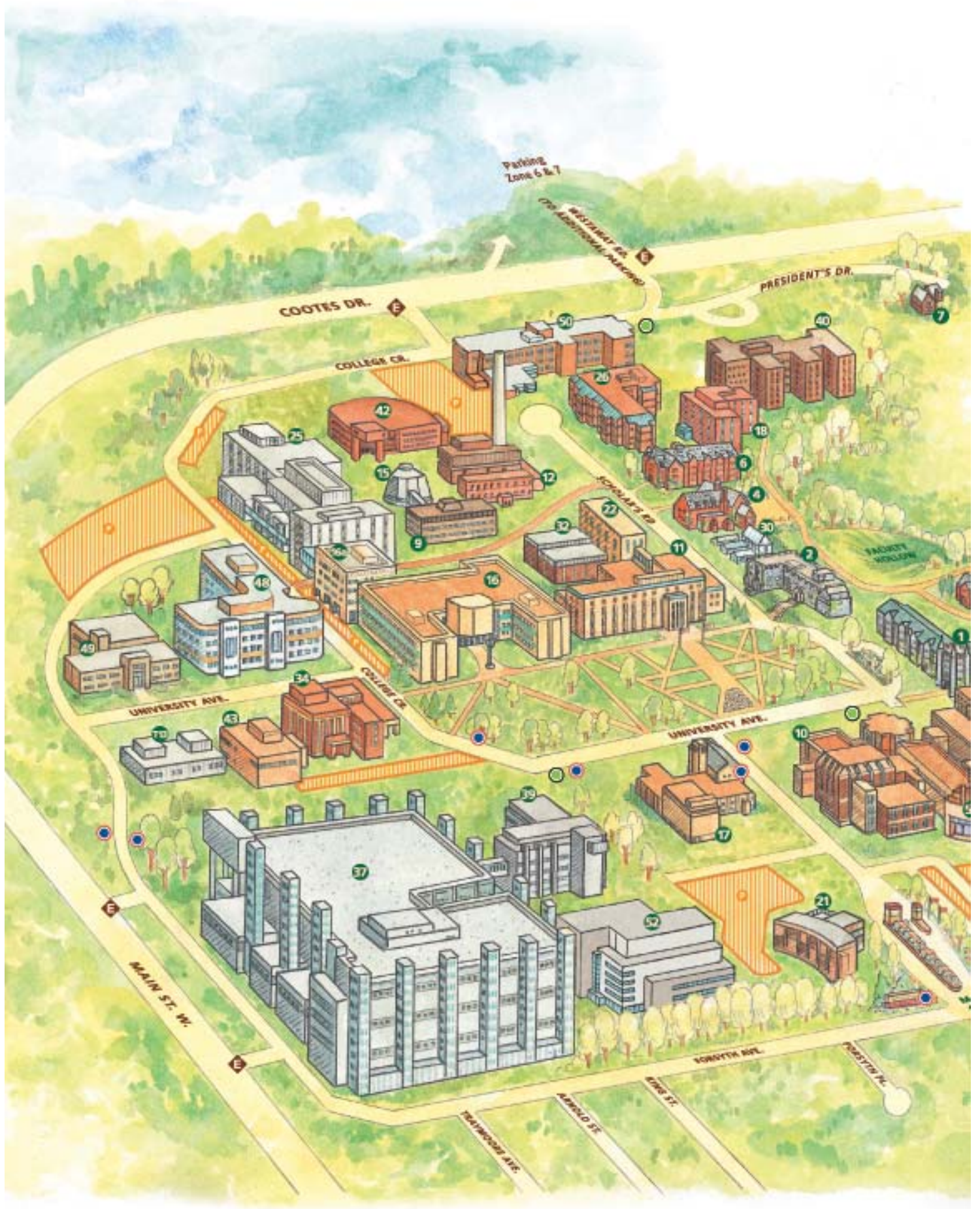
A.G. Kerali

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Abstract

In the last decade, shelter conditions have worsened, and resources have remained scarce. Yet demand for infrastructure continues to rise. The urgency to provide immediate practical solutions is now acute. Unfortunately, it is emerging that even where resources have been provided, highly deficient structures have resulted. Defects were found in foundations, floors, walling, openings, roofs, and in associated civil works, in the majority of recently completed buildings in Uganda. Following a rigorous methodology, investigations were conducted in four regions of the country over a period of three years. It was found that improper procedures adopted before, during and after the building process were responsible for the deficiencies established in 96% of cases investigated, instigating a dramatic upsurge of interest in the building process. Most deficiencies could be attributed to two significant factors, notably; defects (due to building process oversights) in 90 % of all cases, and deterioration (due to natural causes) in 10% of all cases. It was further established that while the latter appeared to be unavoidable, the former was associated to covert and overt omissions, and errors made by the different participants involved in the building process. This paper concludes that it is vital to provide and enforce regulations, and to pursue continuous improvement and awareness through regular training, re-training and refresher courses. Reference materials in the form of manuals and checklists should be provided. The recommendations are likely to apply to building projects world wide, irrespective of the size, scope and location.

Key words: building process, defects, deficiencies, deterioration, and participants.



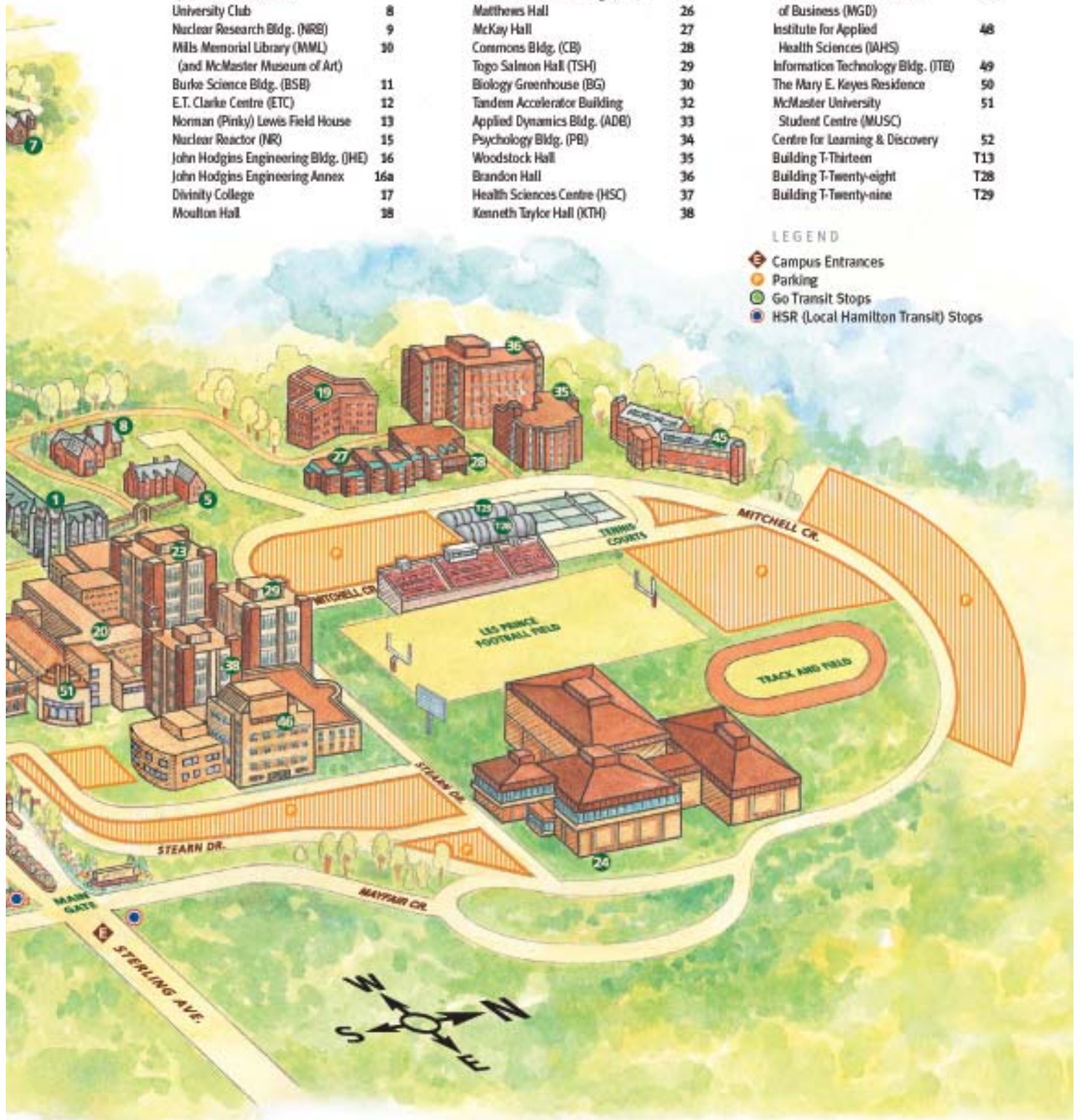
CAMPUS MAP

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(continued) Monday, July 11, 3:00 PM - 4:00 PM

(continued) Analysis, Investigation and Remediation of Structures II, room MUSC 314

Design and Remediation of Overhang Drip Edges

R.H. Fletcher

Principal Fletcher Associates Consulting Engineers

Abstract

Observation of repairs to the facades of two reinforced concrete condominium towers has led to an examination of the causes of failure, particularly of cast-in-place drip edges. The findings show a deficit in the use of materials, the need for better design in facade drainage and the casual treatment of drip edges. A brief survey of drainage design in northern climates shows a marked departure of facade drainage in modern towers from designs used in old buildings. The approach to both design and repairs of reinforced concrete facades has not been incorporated in building guidelines or in prescriptive codes, and will require additional research into the physics of facade drainage and material selection.

Tuesday, July 12, 8:20 AM - 9:10 AM, room MUSC 319

Seismic Rehabilitation of Nonductile Structures

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Abstract

A large proportion of existing building and bridge stock across the world consists of non-ductile structural systems. Performance of structures during recent earthquakes have demonstrated seismic vulnerability of these systems, the majority of which were designed prior to the enactment of modern seismic codes, though some were designed more recently in areas where code enforcement can not be ensured. These structures constitute a tremendous seismic risk, especially in large metropolitan centres. Because it is economically not feasible to replace a large segment of existing infrastructure with seismically superior systems, retrofitting non-ductile systems remains to be a viable seismic risk mitigation strategy. The objective of this paper is to highlight major seismic retrofit strategies for such systems, with emphasis on experimental and analytical research conducted by the author at the University of Ottawa on: i) column retrofitting by external transverse prestressing, ii) column wrapping with fiber reinforced polymer (FRP) sheets, iii) concrete frames with unreinforced masonry (URM) infill walls retrofitted with surface bonded FRP sheets, iv) non-ductile reinforced concrete frames braced by diagonal prestressing, v) the use of active control and smart structure technology for seismic retrofitting non-ductile reinforced concrete frames, and vi) the use of steel strips for seismic retrofitting reinforced concrete, reinforced masonry and URM shear walls. Research findings indicate good to excellent improvements in strength and inelastic deformability of otherwise seismically deficient non-ductile systems.

Keywords: earthquake resistant design; fibre-reinforced-polymers (FRP), masonry walls; prestressed concrete; reinforced concrete; seismic retrofit; smart structures.

Tuesday, July 12, 9:10 AM - 10:00 AM, room MUSC 319

Seismic Retrofit of Steel Structure

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Abstract

This paper provides a brief review of recent work on the development of solutions for the seismic design and retrofit of steel structures by various members of the U.S. research community, including solutions being developed at the University at Buffalo for the seismic retrofit of bridges and buildings. Research applicable to the seismic retrofit of buildings includes work on details for the retrofit of beam-to-column moment connections, research on various innovative structural systems, such as beams with mid-span modifications, self-centering systems, zipper frames, buckling-restrained braced frames, and steel plate shear walls, and research on the development of plastic rotation limits. Research applicable to the seismic retrofit of bridges includes work on shear links and truss piers, including assessment of the cyclic inelastic performance of latticed members, and controlled rocking of truss piers. Note that seismic retrofit solutions can be, in many instances, applicable with little or no modifications to the design of new structures.

Keywords: steel structures, bridges, buildings, seismic, design, retrofit

Tuesday, July 12, 10:30 AM - 12:00 PM

Analysis, Investigation and Remediation of Structures III, room MUSC 309

Finite Element Analysis of Corrosion-Induced Cracking, Spalling and Delamination of RC Bridge Decks

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Abstract

The corrosion of reinforcing steel in reinforced concrete (RC) bridge decks due to the application of de-icing salts in winter has been recognized as one of the major causes of highway bridge deterioration in North America. Corrosion-induced damage is usually manifested by longitudinal cracking, spalling, and/or delamination of the concrete cover due to the expansion of corrosion products accumulating around the reinforcement. This damage leads to reduction or loss of serviceability, safety, and service life of RC bridge decks. This paper presents finite element analyses of the behaviour of the concrete bridge deck cover subjected to reinforcing steel corrosion. The prediction of the damage caused by corroding reinforcing bars is established by calculating the induced stresses in the surrounding concrete. The numerical model is used to conduct a parametric investigation of several design variables. It is found from the analyses that different failure mechanisms govern depending on the geometry and configuration of the reinforcing bars in the concrete cover of the bridge deck. Finally, the impact of concrete overlays on the governing failure modes of cracking, spalling and/or delamination of the concrete cover is investigated by using the model.

Keywords: reinforcement corrosion, longitudinal cracking, spalling, delamination, finite elements.

(continued) Tuesday, July 12, 10:30 AM - 12:00 PM

(continued) Analysis, Investigation and Remediation of Structures III, room MUSC 309

Design of Reinforced Concrete Elements for Durability against Corrosion

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Abstract

Deterioration of reinforced concrete elements subjected to a corrosive environment considerably affects the safety and serviceability of buildings, bridges and other structures. This paper presents a practice-oriented method for the design of flexural concrete elements subjected to chloride-induced corrosion. The reinforcement mass loss due to corrosion is used to correlate the level of corrosion to cracking, bond strength, and to the flexural and shear resistances of the reinforced concrete elements. A method is developed to calculate the critical mass loss ($ML_{critical}$) beyond which there is a significant decrease in bond strength. For corrosion levels less than the $ML_{critical}$, the reduced flexural resistance is calculated using the reduced cross-sectional area. At higher corrosion levels, the flexural strength is based on the residual bond strength. A summary of the procedure and a design example illustrating the effect of chloride-induced corrosion on development length, bond strength, shear and flexural capacity are presented in this paper.

Keywords: durability, corrosion, chlorides, design, flexure, shear, bond

Modelling the Effects of Variations in pH on the Free Chloride Concentration in Concrete

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Abstract

The deterioration of concrete structures due to corrosion of steel reinforcement is generally precipitated by the exposure of reinforced concrete to free chloride ions. Chloride ions in concrete can be found in three forms: (1) free in the pore solution, (2) physically adsorbed to the concrete pore walls, (3) chemically bound to hydration products, but it is the free chlorides that are harmful. However, a decrease in the pH is known to release the bound chloride ions to the pore solution as free chlorides. Carbonation is one reason for pH reduction in concrete and contributes to the release of chemically-bound chlorides. Since a predefined free chloride concentration limit, known as chloride threshold, is used to estimate whether steel depassivation has initiated and corrosion will commence, it is important to determine more accurately the actual amount of free chlorides under specific pH conditions. Here a finite element model is presented, which deals with the interaction between the free chloride concentration and carbonation of concrete structures. The model essentially predicts the free chloride concentration in carbonated concrete under variable environmental and exposure conditions. Since these processes can be affected by several factors including the concrete moisture content, temperature, and chemical composition, the influence of these factors are included in the model.

Keywords: corrosion, concrete, chlorides, alkalinity of concrete, modelling.

(continued) Tuesday, July 12, 10:30 AM - 12:00 PM

Seismic Design and Retrofit of Structures III, room MUSC 314

A Parametric Study on the Seismic Behavior of Liquid Containing Structures Based on ACI 350 Code

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Abstract

The ACI Committee 350¹ has recently published a new code and commentary for liquid containing structures. A companion document, ACI 350.3/350.3R², provides directions to the designer of liquid containing concrete structures for computing seismic forces that are to be applied to a particular structure.

In this paper, a brief overview of the basic concepts involved in the seismic analysis of liquid containing structures is presented. An outline of the basic theory that underlines the computation of earthquake-induced forces is discussed. The specific elastic design response spectrum adopted by ACI 350 is discussed. The correlation between the classical equation and the lateral seismic force equations contained in ACI 350 is presented. The effect of the vertical and horizontal distribution of hydrodynamic forces on the wall of both circular and rectangular tanks is discussed.

In this study, the effect of various parameters on the response of liquid containing structures is presented. With the aid of several design parameters, the behavior of liquid containing structures in terms of impulsive and convective forces, base shear and moment ratios and other design parameters is investigated. Also, the validity of the code procedure for determining the base shear for the impulsive and convective components is discussed using both the distributed and the lumped mass approaches.

Keywords: reinforced concrete, liquid containing, seismic, tank.

A Preliminary Study of a Tuned Liquid Damper with Smart Screens

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Abstract

The *tuned liquid damper* (TLD) as a dynamic vibration absorber is an attractive alternative to the more common *tuned mass damper* (TMD) but has a limited structural response amplitude range of efficiency. This can be attributed to the fact that TLD response is non-linear (amplitude dependent), which increases the complexities of design and analysis, despite that TLDs are relatively simple in construction. This paper presents a background of passive dynamic vibration absorbers, past research and development done to improve the inherent damping of sloshing water TLDs, and current and future work in facilitating the TLD in achieving optimal damping parameters over a larger excitation amplitude range. The latter is to be achieved by inserting "*smart screens*" with a varying loss coefficient to linearize the velocity losses through the screens and create a theoretically constant equivalent linear viscous damping over a large range of excitations. The preliminary analyses set the stage for the extensive research to be conducted including scale model shaking-table experimentation.

Keywords: tuned liquid damper, TLD, slat screens, smart screens, dynamic vibration absorber

(continued) Tuesday, July 12, 10:30 AM - 12:00 PM

(continued) Seismic Design and Retrofit of Structures III, room MUSC 314

Floor Response Spectra for Reinforced Concrete Frame Buildings in Canada

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Abstract

Recent earthquakes have demonstrated the impact of the failure of operational and functional components (OFC) upon life safety and economic losses. Quite often, buildings that sustain only minor damage to their structural elements are deemed unsafe to occupy or operate due to extensive damage to their OFCs. Failure of OFCs and the debris caused by falling objects also pose serious problems for post-earthquake search and rescue missions.

The seismic provisions of the National Building Code of Canada (NBCC) were developed primarily for the design of structural components of new buildings. While the seismic requirements for building structures are well established, the seismic requirements of operational and functional components, which are often referred to as non-structural components, are based on some empirical amplification factors of the seismic effects, which are not documented. Based on the lessons learned from past earthquakes, as well as recent progress in earthquake engineering research, it is clear that a proper seismic design methodology for OFCs should involve the use of representative floor design spectra.

Two 10-storey ductile reinforced concrete frame buildings, one in Ottawa and the other in Vancouver, were selected to develop representative floor response spectra. Dynamic inelastic analyses of buildings were conducted for this purpose under appropriate ground motion records. The paper summarizes the results of the analyses, while presenting a method of developing representative floor design spectra for reinforced concrete frame buildings.

Keywords: earthquakes, frames, nonlinear analysis, non-structural components, operational and functional components, response spectra.

Masonry Materials and Building Envelope III, room MUSC 315

Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing

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Abstract

Typical damage to multiple leaf walls during earthquakes is the loss of bond between the leaves with consequent collapse of half of the wall. Retrofitting or repair of this damage is a very difficult task. In many cases grout injection or wall jacketing fail due to incompatibility with the construction technique of the walls.

A complementary technique to the grouting has been proposed by the authors. Experimental results and applications of the technique on site have shown positive characteristics and the results of tests carried out on site show, in some cases, increases in shear strength and stiffness of the masonry walls.

Keywords: masonry, shear strength, reinforcement, deep repointing

(continued) Tuesday, July 12, 10:30 AM - 12:00 PM

(continued) Masonry Materials and Building Envelope III, room MUSC 315

Hydration of the Condensed Silica Fume in Presence of Lime and Cements

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Abstract

The condensed silica fume (CSF) is used in civil engineering, in particular for the manufacture of high performance concrete. In order to better understand the gain in strength of the concretes containing CSF, the microstructure aspect has been examined. Mixtures of CSF-Lime pastes present a hydraulic setting that is due to the formation of a CSH phase (calcium hydroxide). The latter is semi-crystallized. It is characterized by the lines of x-ray diffraction, hk0 such as: 3.06 Å (220), 2.80 Å (400) and 1.83 Å (040). The mix design CSF-Lime paste is thus a simplified approach of that of the mixtures CSF-OPC in which the main reaction is the fixation, by the CSF, of lime coming from the hydration of C₃S in the form of CSH. Tests have been carried out on two varieties of CSF resulting from the same furnace with the presence of lime or Portland cement. The results show that the presence of certain impurities, by their actions on the solubility of silica played a significant role on the evolution of the hydration of the principal components of Portland cements and the kinetics of fixing the lime by the CSF. Among the impurities contained in the CSF, carbon delays considerably the hydration of the principal components of Portland cement (C₃S and C₃A) as well as the pozzolanic reactivity of the silica fume without removing it.

Keywords: Portland cement, lime, condensed silica fume, kinetics of hydration, speed of dissolution, fixation of lime, impurities.

The Use of Bearing Wedges to Eliminate the Influence of Construction Gaps in Steel Frames Infilled with CASIEL Walls

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Abstract

The process of building walls in already erected frames generally leaves gaps between the frame and infill. This is particularly the case when building infills with calcium silicate elements (CASIELs), whose large size entails handling by means of a small crane. In this investigation, in order to create good contact and bearing between steel frames and infill walls a special construction technique was used. CASIEL wedges were inserted in the middle of a row of CASIELs and pressed so that the rest of the CASIELs move towards the frame. The 3 m by 3 m steel infilled frames were subjected to in-plane monotonic horizontal loading at roof beam level. Infilled frames with gaps below roof beam level are compared with those in which this gap was packed with mortar. This variable, i.e. gaps, is also checked when the frames were constructed with the 'wedge technique'. Load-deformation curves show a three stage response prior to cracking. In general, there is an initial stiff stage before a transition stage during which frame-wall separation occurs and the infill wall glides within the bounding frame. This is followed by another stiff linear load-deflection stiffness response leading to diagonal tension cracking. Shear cracking along the bed joint below the topmost CASIEL layer was observed in some specimens. A construction top gap resulted in reduced second stage stiffness, although it did not reduce the cracking load. By using a bearing wedge in the top corners, the negative influence of the top gap on stiffness was significantly reduced. This may be significant in developing a construction technique for industrial application of infilled frames.

Keywords: infilled frames, CASIELs, thin bed mortar, stiffness, bearing wedge

Tuesday, July 12, 1:00 PM - 2:30 PM

Analysis, Investigation and Remediation of Structures IV, room MUSC 309

Development of a Numerical Tool to Improve the Design of Transmission Towers by Accounting for Downburst Loads

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Abstract

The disruption of electrical services due to failure of transmission towers can have destructive economical and social consequences. In September 1996, Manitoba Hydro reported damage of about \$ 15 Million due to failure of 19 transmission towers during a downburst event. Downbursts can be defined as an intensive downdraft of air that induces very strong wind in all directions when touching the ground. Design codes of practice are based mainly on large-scale windstorms, such as hurricanes. Therefore, conventional design methods of transmission tower structures might not be adequate to account for localized events, such as downbursts. This paper is a part of an extensive study aiming to improve the design procedures of transmission towers by accounting for the effect of downburst loads. The study is conducted numerically where the wind field simulating a downburst is obtained using an impinging wall jet fluid model. One of the Manitoba Hydro towers that failed in 1996 is considered in this paper. The tower is modeled using an assembly of linear 3-D frame elements while the conductors are simulated using a set of non-linear curved beam elements. The non-linear stiffness of the insulator strings that connect conductors to the tower are also incorporated in the model. Three different downburst configurations are presented in the case study. Forces resulting from the downburst configurations are compared to those specified in the design codes based on normal wind loads to assess the importance of considering high intensity wind loads when designing transmission towers.

Keywords: downbursts; finite element; transmission lines; transmission towers; wind load.

Effective Design of Stiffeners on Industrial Ducts

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Abstract

The structural design of industrial air and gas ducts is not governed or referenced by any national code¹. Therefore, engineers commonly use methods that are presented in structural steel codes that primarily focus on building design. Stiffeners on industrial ducts are a major component of the structure. Stiffeners have unique design considerations that make the use of standard code design methods conservative, particularly when considering the performance of stiffeners resisting negative pressure. The results of an analytical design are compared to the results from numerical modeling. The analytical design was found to be conservative by approximately eight times. As validation for the numerical results, a test was performed using a simply supported beam with boundary conditions and applied loads similar to the stiffener assembly, but excluding the effects of the casing.

Keywords: lateral buckling, stiffener, industrial ducts

(continued) Tuesday, July 12, 1:00 PM - 2:30 PM

(continued) Analysis, Investigation and Remediation of Structures IV, room MUSC 309

Moment Resistance of Laterally Unsupported Steel I-beams: A Proposed Equation for LRFD Approach

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Abstract

Local buckling and lateral-torsional buckling significantly affect the behaviour of steel I-beams subject to flexure. The design of laterally unsupported steel I-beams according to LRFD specifications requires the use of multiple equations which depend on the section compactness, the laterally unsupported length of the beam, the geometric properties of the cross section and the yield strength of the steel. Flange outstand-to-thickness and web height-to-thickness ratios define the I-section compactness. The laterally unsupported length of the beam affects the critical moment initiating lateral-torsional buckling. Most codes define three distinct zones with the moment resistance defined by a different equation in each zone. The first and second zones are affected by elastic and elasto-plastic lateral-torsional buckling respectively. The third zone is governed by steel yielding. A single equation for the moment resistance of laterally unsupported steel I-section beams is proposed to cover all of these three zones. Results obtained using the proposed equation are compared to those obtained using CAN/CSA-S16 and AISC-LRFD.

Keywords: lateral-torsional buckling, moment resistance, steel I-beams.

Precast Concrete Drainage Products I, room MUSC 315

Research Suggests Conservative Design of Concrete Box Culverts

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Abstract

U of T research involved 12 major experiments on box culvert sections to develop an understanding of the shear resisting mechanisms for such structures. The crack development, reinforcement strains, and specimen deformation were compared to the results of extensive nonlinear finite element analysis using the computer modeling techniques developed at the University of Toronto. Discussion presented in the report titled, "Shear Behaviour of Concrete Box Culverts: A Preliminary Study" by R.A. Yee, E.C. Bentz, and M.P. Collins, identifies areas of weakness and lack of clarity in the current codes governing box culvert design.

The study developed an experimental procedure to determine the adequacy of the current shear design procedures for a range of commercial box culverts. By comparing the experimental results to the analytical predictions from the shear strength equations in North American codes, the ability of these provisions to predict the shear behavior of the test specimens was examined. The objective of the study is to use the information to provide recommendations to industry outlining the adequacy of commercial box culvert designs in shear, and to more accurately identify where shear reinforcement is required and where it is not. The analytical and experimental results are useful to future box culvert studies and the precast industry, as well as to industry associations and academics involved in researching the shear behavior of concrete structures.

Keywords: shear, box, culvert, precast, strength, reinforcement

(continued) Tuesday, July 12, 1:00 PM - 2:30 PM

(continued) Precast Concrete Drainage Products I, room MUSC 315

Detection of Depth of Surface-Breaking Cracks in Concrete Pipes

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Abstract

This paper presents preliminary results from the nondestructive evaluation of a concrete slab using ultrasonic waves. Based on the transmission coefficient method, a modified testing configuration is introduced, and a new technique called wavelet transmission coefficient is proposed. Preliminary experimental results show a great potential for proposed new methodology.

Keywords: concrete pipes, crack depth, surface waves, transmission coefficient, nondestructive testing.

Current Issues with Dry Cast Concrete Containing Blast Furnace Slag

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Abstract

The amount of ground granulated blast furnace slag (GGBFS) as cement replacement has been limited to 25% for some precast concrete products, which are exposed to freezing and thawing in the presence of deicer salts. However, no published results exist that show the influence of GGBFS on the laboratory scaling resistance of dry cast concrete conducted in accordance with ASTM C 672 or MTO LS-412. This study presents an experimental program, which evaluates the scaling resistance of dry cast concrete conducted in accordance with MTO LS-412. The results reveal that scaling resistance is highly sensitive to the variability associated with surface finishing, and that satisfactory scaling resistance can be achieved for non-air entrained concrete containing up to 40% GGBFS used as cement replacement. The influence and significance of mix design variables, curing and finishing procedure, age of concrete, type of deicer salt and the exposed surface on the scaling resistance are discussed.

Keywords: salt scaling, freeze-thaw, blast furnace slag, durability

Tuesday, July 12, 1:00 PM - 4:30 PM, room MUSC 308

Earthquake Engineering Workshop

Arthur Heidebrecht, Jag Humar, and Murat Saatcioglu

This workshop will highlight salient features of the new seismic design provisions of NBCC-2005. Selected members of CANCEE will present topics on different aspects of code development, including seismicity, design force levels, dynamic and equivalent static analysis methods, as well as other aspects of seismic design.

Tuesday, July 12, 3:00 PM - 4:30 PM

Masonry Materials and Building Envelope IV, room MUSC 309

Further Validation of The Inverse Method for Predicting Air Flow in Buildings

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Abstract

Energy costs, indoor air quality, smoke and fire spread, moisture migration and thermal comfort are all directly affected by a building's airflow regime. It is necessary to understand an existing building's airflow regime, both across its envelope and within its volume, before one can accurately predict building performance. Standard approaches to modeling building air flows involve estimating resistances and then predicting the air pressure field from the airflow field. The output from such models are really only as good as the estimated resistances. This paper examines an alternative to standard building airflow analysis. Airflows within several low-rise buildings are analyzed using an inverse method; the airflow regimes within these buildings are modelled using the readily measured air pressure fields. This inverse method provides an accurate means of predicting a building's airflow field. With further study, this promising method of modeling building performance may be used to provide a quick, efficient method of analyzing the performance of existing buildings.

Keywords: air flow prediction, modeling, inverse method, air pressure, building performance.

The Current Problem Concerning Energy Saving in Buildings and Houses: Analyses, Solutions and a Fast Way for Transferring Research into Practice

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Abstract

Presently, it is not possible to accurately simulate moisture and heat transfer in building envelopes and to identify the best energy saving materials due to a) the absence of data on the conductive component, l_{cond} , of apparent thermal conductivity, l_{app} , of moist building materials and b) the lack of a method for its determination.

l_{cond} is needed for the simulation of moisture and energy transfer/consumption in building envelopes based on the coupled heat and moisture transfer equations.

l_{app} is needed for the traditional estimation of heat resistances of building materials.

This paper presents the major elements of a proposed comprehensive database, that will contain data on the conductive and apparent thermal conductivity of masonry, insulating and other building materials. The approaches being used in the development of the database are based on a combination of theoretical and experimental methods. In this paper examples of developed mathematical models and new data for typical insulation materials in the temperature range of $\pm 50^\circ$ will be discussed.

The created database will cover a practical range of environmental conditions to which the insulation materials could be exposed. The investigated conditions will include, but will not be limited to: variations in temperature $\pm 50^\circ\text{C}$. It will also take into account a variety of insulation materials' properties such as their thickness, orientation in the gravitational field, the influence of ageing on thermal properties, etc.

The suggested database could become an important factor in the design and renovation of efficient building envelopes and low energy consumption buildings and houses.

Keywords: buildings, houses, thermal conductivity, database, moisture, temperature.

(continued) Tuesday, July 12, 3:00 PM - 4:30 PM

(continued) Masonry Materials and Building Envelope IV, room MUSC 309

Assessing Sustainability in the Construction Industry

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Abstract

BASF applies two tools to address the economic, environmental and social aspects of building sustainability: Eco-efficiency Analysis and SEEBalance[®] (socio-eco-efficiency analysis).

BASF's eco-efficiency methodology evaluates the environmental and economic impacts of products and processes. Based upon the principles of ISO 14040, it contains additional enhancements that allow the results to be used as a concise decision-making tool. Six environmental categories are evaluated:

- Raw materials consumption
- Energy consumption
- Land use
- Air, water and solid waste emissions
- Toxic potential of the substances employed and released
- Potential for misuse and risk potential.

Life-cycle data are compiled for each of these categories, a weighting scheme is used to aggregate the results, and they are normalized in order to generate an ecological fingerprint. An economic analysis is also done to address costs over the life cycle of the product. The economic results are then combined with the environmental results to obtain the portfolio, which concisely depicts the relative eco-efficiencies by showing the total environmental impact on the y-axis, and the total cost impact on the x-axis.

SEEBalance[®] is a recently developed tool that incorporates the social dimension of sustainability. Socio-eco-efficient solutions combine a relatively good environmental performance with high social benefit and at the same time low costs for the end customer. The final aggregation and presentation of the results is done in an analogous manner as in the eco-efficiency analysis.

These two methodologies are explained and case studies related to the construction industry are presented.

Keywords: eco-efficiency, BASF, socio-eco-efficiency, SEEBalance[®], sustainability

Precast Concrete Drainage Products II, room MUSC 315

Field Performance of a Concrete Pipe Culvert Installed Using Standard Installations

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Abstract

In August 2000, a concrete pipe culvert of 1370 mm inside diameter was installed under a truck route in the former Regional Municipality of Ottawa-Carleton (now City of Ottawa) using the Standard Installations method. The project demonstrated two installation conditions, known as Type 2 and Type 3. In order to evaluate the pipe performance and verify the Standard Installations theory, two pipe sections were instrumented to evaluate the loading conditions and enable a comparison of the Standard Installations theory. The performance monitoring conducted over a three-year period showed good correlation with the Standard Installations theory. The measured performance of the pipe from the test site compared to the predicted performance for Standard Installations has resulted in some very informative findings on the interaction between pipe and soil, and provides the owners of infrastructure with design options for concrete pipe. This research offers a cost effective alternative to the current design method developed more than seventy years ago.

Keywords: structural, loading, standard installations direct design

(continued) Tuesday, July 12, 3:00 PM - 4:30 PM

(continued) Precast Concrete Drainage Products II, room MUSC 315

Indirect Design Method – Marston Spangler Method of Estimating Loads on Buried Pipe

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Abstract

The Indirect Design Method is the most commonly used procedure for specifying concrete pipe. In this approach, the required strength of the pipe is determined and then a class of pipe is selected that meets that load requirement based on a given bedding design. By using a table, the pipe manufacturer selects the reinforcing steel required in the pipe.

However, in some extreme cases the particular class of pipe may not be suitable. For example, the pipe may be required to meet strengths above and beyond the highest classification listed in tables, or a more exacting design may be appropriate. In such situations, designers can use the direct design method to consider flexure, shear, radial tension and crack control, thereby directly determining the reinforcement required to meet the specific project criteria.

In the Indirect Design Method, the earth pressures and their distribution around the pipe and the resulting moments, thrusts, and shears in the pipe are not calculated. Instead, procedures developed by Anson Marston and Merlin G. Spangler are used to calculate bedding factors for the pipe, which relate the in-situ load to the pipe to the load applied in a three-edge bearing test.

Keywords: Marston, Spangler, bedding factors, load, pipe

Effect of Metal Oxide Coating on Generation of Sulfide in Concrete Sewer Pipes

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Abstract

Hydrogen sulfide is a serious problem for many municipalities across North America, and worldwide. Odor, safety problems, and corrosion are the major problems associated with the presence of hydrogen sulfide in sewage systems. This paper investigates the effect of using innovative coatings on sulfide generation in concrete sewer pipes. A pilot-scale model, consisting of three concrete pipes (each 75 cm in length and 30 cm in internal diameter), was used to simulate the process of sulfide generation in a sewer system. Two of the pipes were internally coated with either cuprous oxide or silver oxide, while the third one served as a control. Each of the oxides were mixed with a commercial epoxy, used for repairing concrete sewer pipes, prior to spraying on the internal surface of the concrete pipe specimens to form a coating film. Test data showed that the sulfide generation by *Desulfovibrio Desulfuricans* in the cuprous oxide and silver oxide coated pipes was reduced by 92% and 100%, respectively, compared with that of the control pipe. The coating films also effectively decreased the bacterial count in the nutrient solution.

Keywords: hydrogen sulfide, coatings, cuprous oxide and silver oxide.

Wednesday, July 13, 8:30 AM - 9:30 AM, room MUSC 319

A Framework for Durability Design of Infrastructure

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Abstract

This paper emphasizes the need to consider the life cycle performance of any infrastructure facility in its design, construction, maintenance, operation, and when needed its rehabilitation. To fulfill the requirements of the ultimate and the serviceability limit states over the facility service life requires an understanding of the deterioration response of the materials and their components, when subjected to aggressive environments.

The composition, microstructure, macrostructure and the various modes of deterioration for steel, wood and concrete are reviewed, along with possible remedial measures. The development of concrete as a construction material and its durability, and the durability provisions in the various CSA standards relating to concrete, are reviewed briefly.

The current European practice and the 1990 CEB Design Guide for Durable Concrete Structures are summarily evaluated. The engineering responsibility for durable performance of a facility and the importance of durability audits to help achieve these goals are also examined.

Keywords: concrete, construction materials, deterioration, durability, durability audits, life cycle performance, macrostructure, microstructure, steel, sustainability, wood

Wednesday, July 13, 9:30 AM - 10:00 AM, room MUSC 319

Engineering the Future: Adapting the Civil Infrastructure in a Changing Climate

M. Mortimer

Canadian Standards Association

Wednesday, July 13, 10:30 AM - 12:00 PM

Masonry Materials and Building Envelope V, room MUSC 309

Freeze-thaw Durability of Concrete Masonry Products

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Abstract

Despite the significant growth in the use of concrete masonry products in North America in the past decades, the durability of these products under repeated freeze-thaw (F/T) (and including deicing salt scaling) is still a concern. Owing to their production technology, concrete masonry products are dry cast (dry concrete), which results in a microstructure that is different than that of normal concrete. A review of the literature reveals the need for more research to better understand the F/T behavior of these products. It also shows the inadequacy of specifications in national standards to ensure the F/T durability of these products. Published studies indicate several parameters affect the F/T durability. The relative influence of these factors and their effect on the microstructure need to be more clearly understood in order to enable the consistent production of durable masonry products under repeated action of F/T.

Keywords: concrete masonry products, freeze-thaw, durability, dry concrete, deicing salt scaling

(continued) Wednesday, July 13, 10:30 AM - 12:00 PM

(continued) Masonry Materials and Building Envelope V, room MUSC 309

Lightweight Concrete with Pumice Aggregate: Mix Design and Fire Resistance

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Abstract

Volcanic pumice is found in various parts of the world including Canada. This paper presents the development of volcanic pumice concrete (VPC) using lightweight pumice aggregate illustrating mix design procedures with tables and charts for specified compressive strengths. Investigation suggests that it is possible to produce a VPC for structural applications that is 30% lighter than normal concrete (NC) and of satisfactory strength. This paper also describes the fire durability of lightweight VPC. Both VPC and NC specimens are subjected to elevated temperatures (maximum up to 800°C) for different duration (maximum up to two hours). Performance is judged based on residual strength and physical changes of VPC compared with NC. The strength of both VPC and NC is found to decrease with the increase of duration of fire and temperature. VPC shows better residual strength compared to NC after exposure to elevated temperature for different duration although variability of test data may also be a contributing factor. The better performance of VPC, although the variability of test data may also be a contributing factor. The use of VPC, especially in volcanic areas around the world can provide low cost housing and lead to sustainable construction.

Keywords: volcanic pumice, lightweight concrete, strength, fire durability, mix design

Development of a Finite Element Program for Three-Dimensional Nonlinear Analysis of Reinforced Masonry Buildings

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Abstract

Many factors have to be considered in order to accurately predict the structural behaviour of reinforced masonry shear wall buildings under the combined effects of gravity and lateral loads. These include the three dimensional interaction between the individual walls, the influence of the rigidity of the floor diaphragm, the effects of shear deformations and wall perforations, the variability of the distribution of horizontal and vertical steel and the effect of cracking and material nonlinearity. This paper describes a user-friendly, three-dimensional finite element code that was developed to address all the above-mentioned factors. In this program, individual elements are modeled using two-dimensional plane stress elements. The element size is selected such that a typical concrete block is modeled using two elements. The in-plane rigidity of the floor slabs is also simulated using an assembly of plane stress elements. The interaction between various components of the model is achieved by applying the proper compatibility of displacements between these components. The distribution of gravity loads between various walls is evaluated internally through modeling of typical floors using an assembly of shell elements. A nonlinear material model for reinforced block masonry that takes into account the effects of cracking and biaxial stresses is included in the model. A pre-processor that enables the creation of a three-dimensional model of an entire building by specifying only a few parameters has been developed. Deformations, stress and strain contours, values of principal stresses and strains, and internal forces acting on piers and walls are provided by a post processor. To illustrate the benefit of the numerical tool, a masonry building is analyzed using both the developed software and the simplified procedure commonly applied in the consulting industry. The results are compared to assess the importance of conducting more thorough analyses of shear wall buildings.

Keywords: analysis, finite element; masonry, buildings, lateral loads.

(continued) Wednesday, July 13, 10:30 AM - 12:00 PM

Seismic Design and Retrofit of Structures IV, room MUSC 314

Dynamic Behaviour of the Confederation Bridge due to Seismic Loads

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Abstract

The 12.9 km Confederation Bridge, crossing the Northumberland Strait in eastern Canada, is one of the longest reinforced concrete bridges in the world. In the design of the bridge, the seismic hazard for the bridge location was represented by a seismic design spectrum. This spectrum was derived by applying spectral amplification factors to the peak ground acceleration, velocity and displacement, corresponding to the design life of the bridge of 100 years. The design forces and displacements due to seismic loads were computed using the modal response spectrum method.

This paper describes results from a study on the dynamic behaviour of the Confederation Bridge due to seismic loads. The seismic hazard for the bridge location was represented by a uniform hazard spectrum corresponding to the most recent seismic hazard models. For the purpose of the seismic analysis of the bridge, a finite element model was developed using 3-D beam elements. The model was calibrated using measured data of the bridge vibrations during a dynamic load test. Dynamic time-history analyses were conducted by applying seismic excitation motions corresponding to the seismic hazard of the location. The bending moments and the displacements obtained from the seismic analysis were compared with the design values. It was found that the seismic effects used in the design are quite representative of the seismic hazard of the bridge location.

Keywords: bridge, dynamic, analysis, seismic, response, spectrum.

Explicit Finite Element Approach for Effective Collapse Simulation of Steel Box Bridge Piers under Multi-directional Earthquake Loading

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Abstract

A number of steel bridge piers sustained substantial damage during the recent major earthquakes including the Northridge Earthquake of 1994 in the United States and the 1995 Hyogo-Ken Nanbu Earthquake (Kobe), Japan. Many currently existing structures in earthquake prone regions were designed and constructed in accordance with codes developed in the 1970's and 1980's that neglected multidirectional excitation. As a result, both experimental and numerical research has been conducted to identify causes of failure for more effective structural analysis and design. On the numerical front, employment of implicit Finite Element Analysis (FEA) solvers for Time History Analysis (THA) was the norm due to their expedience. This paper explores the prospects of using explicit FEA solvers which can offer more modeling capabilities in nonlinear transient analysis involving contact and severe deformation, and simulating the sequence of events leading to failure. Specifically, this explicit FEA investigates the response of corner welded box steel piers to transient seismic excitation, as well as the effect of structural pounding as a substantial cause of failure for adjacent structures. It is demonstrated that explicit solvers have practical simulation potential for seismic analysis applications in civil engineering. Additionally it is demonstrated that consideration of multi-component earthquake excitation is crucial when designing for extreme seismic events.

Keywords: explicit finite element analysis, steel bridge piers, time history analysis.

(continued) Wednesday, July 13, 10:30 AM - 12:00 PM

(continued) Seismic Design and Retrofit of Structures IV, room MUSC 314

3-D Nonlinear Finite Element Modeling of Cable-stayed Bridge

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Abstract

A 3-D nonlinear analysis of a cable-stayed bridge by finite element method is presented in this paper. Various nonlinearity concepts in cable-stayed bridges are described. A realistic analytical cable-stayed bridge model is developed by using SAP2000 finite element program. The static and dynamic response of the cable-stayed bridge under dead load, live load and seismic load is investigated, taking the effects of several nonlinearities into account. Forces and deformations of the members due to various load combinations are calculated. The effect of the distribution of the cable tensioning on the bridge performance and the seismic behavior of the “floating deck system” of the cable-stayed bridge are also discussed.

Keywords: cable-stayed bridge, modeling, nonlinearity, finite element method

Analysis, Investigation and Remediation of Structures V, room MUSC 315

Development of Ultra-Lightweight Concrete and Concrete Products

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Abstract

In this study, concrete with strengths from 5 to 50 MPa and densities from 800 to 1400 kg/m³ is designed and tested. The compressive strength to flexural strength ratio increases as the compressive strength of the concrete increases. The concrete has excellent thermal insulation property and fire resistance. Several full-scale production demonstrations indicate that it can be used for manufacturing different non-load bearing and load bearing precast concrete products such as panels, modular and blocks.

Keywords: lightweight concrete, strength, fire resistance, panels, concrete products

(continued) Wednesday, July 13, 10:30 AM - 12:00 PM

(continued) Analysis, Investigation and Remediation of Structures V, room MUSC 315

Recommendation of Response Modification Factor (R) for Concrete Shaft Staging Elevated Tanks

M. Masoudi¹ and M. Ghafory-Ashtiany²

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Abstract

In this paper for determination of failure mechanism in concrete elevated tanks with shaft staging, seismic behaviour of these types of structures is evaluated. Then for achieving Response Modification Factor (R), a computer model of a shaft staging elevated tank has been built. By using linear and nonlinear time history analysis method for 9 different earthquakes, effect of multi components of earthquake, liquid-structure interaction and $P-\Delta$ on nonlinear performance has been determined and discussed. At the end, (R) factor for shaft staging concrete elevated tanks regarding the seismicity of the site has been recommended.

Keywords: elevated tank, shaft staging, earthquake response, nonlinear analysis, liquid-structure interaction, response modification factor.

Recommendation of Response Modification Factor (R) for Concrete Frame Staging Elevated Tanks

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²Professor and President, International Institute of Earthquake Engineering & Seismology (IIEES), Tehran, Iran, Ashtiany@iiees.ac.ir

Abstract

In this paper for determination of failure mechanism in concrete elevated tanks with Frame staging, seismic behaviour of these types of structures is evaluated. Then for achieving Response Modification Factor (R), a computer model of a Frame staging elevated tank has been built. By using linear and nonlinear time history analysis method for 9 different earthquakes, effect of multi components of earthquake, fluid-structure interaction and $P-\Delta$ on nonlinear performance has been determined and discussed. At the end, (R) factor for frame staging concrete elevated tanks regarding the seismicity of the site has been recommended.

Keywords: elevated tank, frame staging, earthquake response, nonlinear analysis, liquid-structure interaction, response modification factor.

Wednesday, July 13, 1:00 PM - 4:00 PM, room MUSC 308

Masonry Workshop

Robert Drysdale and David Stubbs

This workshop highlights areas from the recently published 2004 edition of the masonry design and related standards to explain new or improved design and construction requirements and to provide worked out practical examples.

General Information

WELCOME RECEPTION

Schedule: Sunday, July 10, 2005, 6:00PM – 8:30PM

Location: University Club, McMaster University

All conference participants, accompanying persons and students who have registered for the conference are invited to the Welcome Reception. Enjoy a complimentary drink and a variety of hot and cold hors d'oeuvres in an informal atmosphere (cash bar service available). This reception is ideal for networking, making new friends and reconnecting with old acquaintances.

ICEBREAKER

Schedule: Monday, July 11, 2005, 6:00PM – 8:00PM

Location: MUSC Atrium/McMaster Museum of Art, McMaster University

All conference attendees who have registered for the entire conference (i.e. Authors, Delegates, Students), or individuals who have purchased a one-day pass plus an icebreaker ticket, or companions of attendees who have purchased an icebreaker ticket are invited to attend an icebreaker cocktail party in a semi-formal atmosphere. Enjoy hot and cold hors d'oeuvres and a complimentary drink (cash bar service available) while you listen to live music and peruse the art collections in a private viewing of the McMaster Museum of Art.

BANQUET DINNER

Schedule: Tuesday, July 12, 2005, 6:00PM – 11:00PM

Location: Grand Central Ballroom, Liuna Station, Hamilton

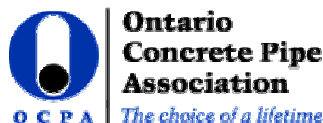
All conference attendees who have registered for the entire conference (i.e. Authors, Delegates, Students), or individuals who have purchased a one-day pass plus a banquet ticket, or companions of attendees who have purchased a banquet ticket are invited to the Banquet dinner. Located in Hamilton's historic Liuna Station, this evening is a must for all! This formal affair will begin with a reception at 6:00PM, followed by dinner and presentations from 7:00PM – 9:00PM. *Kanata*, a six nations aboriginal group, will provide entertainment from 9:00PM – 10:00PM. Presented in traditional ceremonial attire, the group will perform a series of dances while discussing the history and traditions of their people in Canada, specifically southwestern Ontario. Following this presentation, an hour of dancing and socializing will bring this evening to a close.

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