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CANADIAN CIVIL ENGINEER

L'INGÉNIEUR CIVIL CANADIEN

2013 | WINTER/HIVER

- Launched-girder technique at Cornwall
- Applications of shape memory alloys
- UHPC: Hodder Avenue underpass
- St. Charles River clean-up

Materials for the 21st Century

Les matériaux du 21e siècle

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CANADIAN CIVIL ENGINEER
L'INGÉNIEUR CIVIL CANADIEN

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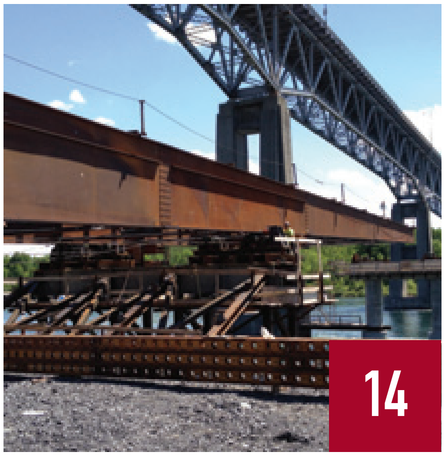
Cover photograph: Detail from Hodder Avenue Underpass, Thunder Bay, Ont.. Courtesy Ductal-Lafarge.



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FORUM ON SUSTAINABILITY

NEWS, VIEWS & DEPARTMENTS/ NOUVELLES, POINTS DE VUE ET DÉPARTEMENTS

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Sustainability Rating System for Infrastructure

In my last column I introduced the concept of sustainable infrastructure in the context of sustainable communities. Infrastructure systems combine at the community level, providing the support systems that form the foundation for viable and successful communities. The "sustainability quadrant" was identified with the view that communities/countries must gravitate toward sustainability by sustaining their human development index (i.e. social support systems – health, education, economics, etc.) and reducing their ecological footprint (i.e. environmental impacts from GHG emissions, etc.). This approach suggests a basis for measuring the sustainability of infrastructure by looking at the social, financial and environmental factors at the community level. The idea of a sustainability rating system for infrastructure measurement has already been initiated in several countries around the world. To be truly sustainable, the rating system needs to be linked to these issues associated with global sustainability. This raises the question of a Canadian sustainability rating for infrastructure.

A number of national organizations have initiated informal discussions to review the concept of developing a Canadian sustainability rating system. CSCE has been a key member of this discussion group that includes the Canadian Pubic Works Association (CPWA), the Association of Consulting Engineering Companies (ACEC) and the Canadian Construction Association (CCA). One of the principles discussed by this group was to not reinvent the wheel. If there is a system in use in another country that could be applicable in Canada it should be researched for adaptation/adoption rather than developing a new system. This led to the first activity of the group by going through an investigation and assessment of the rating systems in use around the world.

One such system has been developed and is beginning to be introduced by our neighbours to the south. The Institute for Sustainable Infrastructure (ISI) has created the Envision sustainability rating system in collaboration with the Zofnass Program for Sustainable Infrastructure at Harvard University Graduate School of Design. ISI is a creation of the American Society of Civil Engineers (ASCE), the American Council of Engineering Companies (ACEC) and the American Public Works Association (APWA).

The Envision rating system, in ISI's own words, "provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle." (See CIVIL Spring 2013, "Evaluate Projects Through the Windows

That Matter to Society" for more information about Envision.)

Such an approach is key if we are to make the types of changes in the development and management of our infrastructure that will make a difference in the sustainability of our communities. The idea of rating infrastructure in this context is viewed as an important component of a change process with the basic premise: what gets measured gets managed. The key word for me is "transformational." In the end, Canadians must transform the way we think about, plan and implement infrastructure systems such that we do not continue to do the same thing the same way and expect any different result in terms of our social responsibilities for sustainability at a global level. CSCE intends to be a leader in this endeavour. ■

Un système d'évaluation de la durabilité pour les infrastructures

Dans mon dernier message, je mentionnais la notion d'infrastructure durable dans le contexte de collectivités durables. Les infrastructures se rejoignent au niveau des communautés, fournissant les systèmes qui constituent la base de communautés viables et réussies. On a déterminé la « zone de durabilité » en considérant que les collectivités/pays devaient évoluer vers la durabilité en développant leur indice de développement humain (par ex. : les systèmes d'appui social en matière de santé, d'éducation, d'économie, etc.) et en diminuant leur empreinte écologique (par ex. : l'impact environnemental des gaz à effets de serre, etc.). Cette démarche suggère la possibilité de mesurer la durabilité des infrastructures en étudiant les facteurs sociaux, financiers et environnementaux au niveau de la communauté. L'idée d'un système d'évaluation des infrastructures a déjà été amorcée dans plusieurs pays du monde. Pour être vraiment durable, un ouvrage doit être reliés à ces questions qui sont associées à la durabilité globale. Voilà ce qui soulève la question d'un système canadien d'évaluation des infrastructures.

Certains organismes nationaux ont entrepris des discussions informelles pour étudier l'idée d'élaborer un système canadien d'évaluation des infrastructures. La SCGC était un membre-clé de ce groupe, qui comprenait l'Association canadienne des travaux publics (ACTP), l'Association des sociétés de génie conseil et l'Association canadienne de la construction. L'un des principes étudié par ce groupe était de ne pas essayer de réinventer la roue. S'il existe, dans un autre pays, un système qui serait applicable au Canada, il faudrait l'étudier pour fin d'adaptation/adoption, plutôt que de créer un nouveau système. Ceci a mené à la première activité du groupe, qui a procédé à l'étude et à l'évaluation des systèmes d'évaluation à travers le monde.

Un tel système a été créé par nos voisins du sud et commence à être appliqué. Le « Institute for Sustainable Infrastructure (ISI) » a créé le système d'évaluation « Envision », en collaboration avec le « Zofnass Program for Sustainable Infrastructure », à la « Graduate School of Design » de l'Université Harvard. L'ISI est une création de l'American Society of Civil Engineers (ASCE), l'American Council of Engineering Companies (ACEC) et de l'American Public Works Association (APWA).

Le système d'évaluation « Envision™ », selon l'ISI… « fournit un cadre global pour évaluer les avantages communautaires, environnementaux et économiques de toutes les sortes d'infrastructures. Il évalue, classe et tient compte des infrastructures qui utilisent des démarches de transformation et de collaboration pour évaluer les indices de durabilité pendant le cycle de vie d'un ouvrage. » (Voir dans CIVIL, printemps 2013, l'article intitulé « Evaluate Projects Through the Windows That Matter to Society » pourf en savoir plus sur « Envision ».)

Ce genre de démarche est capitale si nous devons effectuer à la création et à la gestion de nos infrastructures le genre de changements qui affecteront la durabilité de nos collectivités. L'idée d'évaluer les infrastructures dans un tel contexte est considéré comme une importante composante d'un processus de changement, en tenant compte de la prémisse de base suivante : tout ce qui est mesuré est aussi géré. Pour moi, le mot clé ici est le mot « transformation ». En dernière analyse, les Canadiens doivent transformer leur façon de penser, de planifier et de mettre en œuvre les infrastructures, de telle sorte que nous ne continuerons pas de faire la même chose en espérant des résultats différents en termes de responsabilité sociale au niveau global. La SCGC compte bien être un leader dans cette démarche. ■

London & District Section: The Coming Year

Tom Mara, Ph.D., P.Eng., M.CSCE
CHAIR, LONDON & DISTRICT SECTION, CSCE

The London & District Section, based in London, Ont., is a joint section of the Canadian Society for Civil Engineering (CSCE) and Canadian Geotechnical Society (CGS). The Section Executive has strong ties with Western University, and comprises a cross-section of local industry members, professors, and students. In developing our program, we try to ensure that our focus is aligned with the three CSCE strategic directions: providing enhanced services to members; growing with youth; and providing leadership in sustainable development. This effort is compatible with our CGS goals as well.

The Section typically hosts seven dinner meetings every year, with participation ranging from 20-45 people.

The coming year will be marked by the ongoing organization process for the 2016 CSCE Annual Conference. The participation of a variety of local public and private sector engineering organizations, as well as professors at Western University, bodes well for a comprehensive and dynamic conference.

The 2013-2014 season began with a National Lecture Tour presentation on Canada's Infrastructure Report Card by Reg Andres and Nick Larson. Other topics scheduled for the coming year include: the Niagara Tunnel project; a tour of the new WindEEE Research Institute; the impact of built heritage on engineering projects; repair of the Lynn River lift bridge; geologic controls and disposal of excess soil from construction; and challenges of condition assessment for the Lake Huron primary water supply system.

The Section is a proud supporter of many teams and events at Western University, including the concrete canoe and toboggan teams, and the Polar Stick Bridge Competition. The Executive is hoping to see another solid Western performance at the next Great Northern Concrete Toboggan Race, hosted by Western from Jan. 29-Feb. 2, 2014. We also sponsor an annual CSCE student award.

I would like to extend a warm invitation to anyone interested in either becoming involved with any of the events or opportunities mentioned above or attending one of our meetings. Visit www.csce-cgs-london.org for details. ■

CSCE/CGS London & District Executive / L'exécutif de la section.

Section de London & District : l'année qui vient

Tom Mara, Ph.D., ing., M.SCGC
PRÉSIDENT, SECTION DE LONDON & DISTRICT, SCGC

La section de London & District, qui est basée à London, ON, est une section conjointe de la Société canadienne de génie civil (SCGC) et de la Société canadienne de géotechnique (SCG). L'exécutif de la section entretient des liens étroits avec l'Université Western et comporte un échantillonnage, d'industriels, de professeurs et d'étudiants de la région. Dans l'élaboration de notre programme, nous essayons de tenir compte des trois orientations stratégiques de la SCGC : améliorer les services aux membres ; croître avec les jeunes ; assurer un leadership en matière de développement durable. Cet effort est également compatible avec les objectifs de la SCG.

La section organise à chaque année sept activités sociales, dont la participation varie entre 20 et 45 personnes.

L'année qui vient sera marquée par l'organisation du congrès annuel de la SCGC de 2016. La participation de divers organismes d'ingénierie locaux, publics et privés, ainsi que de professeurs de l'Université Western, permet d'anticiper un congrès dynamique et global pour 2016.

La saison 2013-2014 a démarré avec une visite de la Tournée nationale de conférences portant sur le Bulletin canadien des infrastructures, avec Reg Andres et Nick Larson. Les autres sujets au programme pour l'année sont : le projet du tunnel Niagara ; une visite du nouveau « WindEEE Research Institute » ; l'impact de l'héritage bâti sur les projets de génie ; la réparation du pont levant de Lynn River ; les contrôles géologiques et l'élimination des surplus de terre provenant de la construction, et les défis de l'évaluation de l'état du système primaire d'approvisionnement du lac Huron.

La section appuie nombre d'équipes et d'activités à l'Université Western, dont l'équipe du canot en béton, l'équipe du toboggan en béton , le concours « Polar Stick Bridge », et la commandite du prix annuel décerné par la SCGC à un étudiant exceptionnel. L'exécutif se réjouit de la bonne performance de l'Université Western à la course de toboggans en béton du grand nord de 2014, qui est organisée par l'Université Western, du 29 janvier au 2 février 2014.

J'invite tous les intéressés à participer aux activités de la section. Consultez notre site web à l'adresse www.csce-cgs-london.org. ■

New CSCE Student Chapter Formed at University of Victoria

By Dr. Rishi Gupta, faculty advisor, and Simon Citerneschi and Alex Eichhorn, co-chairs, UVic Student Chapter

A new student chapter of the Canadian Society for Civil Engineering has been formed at the University of Victoria. The student chapter kick-off event was held Sept. 12. It featured presentations by Kevin Baskin, MOTI (chair, Vancouver Island section, CSCE); Carl Wong, MOTI (young member coordinator, CSCE); Dr. Caterina Valeo, UVic (civil engineering program co-ordinator); and Dr. Rishi Gupta, UVic (treasurer, Western region, CSCE).

The presentation included details about CSCE, membership benefits, and the formation of a new CSCE student chapter at UVic. It formally opened the floor for members of the civil engineering cohort to acquire membership and to develop the first executive committee.

Currently, the newly elected executive committee is working to promote the student chapter among students and industry, as well as setting up events for the upcoming year. The first social event has already been concluded. Other events being considered for this term are a site tour of the Johnson Street Replacement Bridge in Victoria, a popsicle stick bridge building competition at the Uni-

CSCE UVic Student Chapter Executive / L'exécutif du chapitre étudiant de la SCGC à l'UVic (2013-2014). L to R/ de gauche à droite : Kears Porttris, Andrew White-Deshamois, Usman Khan, Simon Citerneschi (co-chair/co-président), Stefanie Cutler, Alex Eichhorn (co-chair/co-président), Teresa Cutler, Adham El Newihy, Kris Plata. Not in the photo/n'apparaissent pas sur la photo : Jacob Pez, Kristina Frolova, Dr. Rishi Gupta (faculty advisor/conseiller de faculté).

versity of Victoria, and social gatherings exclusive to members, including networking events and industry night.

The student chapter is looking to connect with fellow CSCE chapters as well as seeking connections and potential sponsorship from industry. Anyone interested in working with the student chapter should write to csce@uvic.ca. The student chapter acknowledges the support from CSCE's Western region, Vancouver section and Vancouver Island section for providing seed funding for our chapter. The support of the National office with our membership drive is also greatly appreciated.

Un nouveau chapitre étudiant de la SCGC à l'Université de Victoria

Par Rishi Gupta Ph.D., conseiller de faculté, et Simon Citerneschi et Alex Eichhorn, co-présidents, du chapitre étudiant de l'UVic

Un nouveau chapitre étudiant de la Société canadienne de génie civil a été créé à l'Université de Victoria. L'activité de lancement du chapitre étudiant a eu lieu le 12 septembre, avec un exposé de Kevin Baskin, MOTI (président de la section de la SCGC de l'île de Vancouver) ; Carl Wong, MOTI (coordonnateur des jeunes membres de la SCGC) ; le professeur Caterina Valeo, UVic (coordonnateur du programme de génie civil) ; et le professeur Rishi Gupta, UVic (trésorier, région de l'Ouest de la SCGC).

L'exposé comportait des détails sur la SCGC, les avantages offerts aux membres et la formation d'un nouveau chapitre étudiant à l'UVic. Il invitait les membres de la profession à devenir membres et à créer le premier comité exécutif.

En ce moment, le comité exécutif nouvellement élu travaille à la promotion du chapitre étudiant auprès des étudiants et de l'industrie ainsi qu'à l'organisation d'activités pour l'année qui vient. La première activité sociale a déjà eu lieu. D'autres activités sont à l'étude pour ce mandat, dont une visite au chantier pour le remplacement du pont de la rue Johnson, à Victoria, un concours de ponts en bâtons de popsicle à l'Université de Victoria, et des rencontres sociales réservées aux membres, des activités de réseautage et des soirées avec des industriels.

Le chapitre étudiant cherche à rejoindre les autres chapitres étudiants de la SCGCet à établir des commandites avec l'industrie. Toute personne intéressée à travailler avec le chapitre étudiant peut s'adresser à csce@uvic.ca. Le chapitre étudiant remercie pour leur appui la région de l'Ouest de la SCGC, la section de Vancouver et la section de l'île de Vancouver, qui ont financé le lancement de notre chapitre. Nous avons également apprécié l'aide de la permanence dans notre campagne de recrutement.

YOUNG PROFESSIONALS' CORNER | LE COIN DES JEUNES PROFESSIONELS

Young Professionals Across Canada: Western Region

By Nigel Parker, EIT, M.Eng, LEED AP BD+C, AMCSCE
CHAIR, CSCE YOUNG PROFESSIONALS COMMITTEE

In the second of our series of articles featuring highlights of Young Professional (YP) events held, or to be held, we feature the Alberta sections of the Western region.

Calgary

The Calgary Young Professionals chapter has been collaborating with the student chapter at the University of Calgary on events this fall. A mixer that brought together new professionals and students in an informal setting took place on the evening of September 25, 2013. The two chapters would also like to co-host a tour later this year. The Calgary YP vision for this upcoming season is to bring together young professionals from different backgrounds; to connect with students that are the future; and to build long lasting professional relationships.

-- Chelsea Smolka, EIT, AMCSCE

Edmonton

To finish off the 2012/2013 season, the Edmonton Young Professionals "YoPros" spent a Sunday afternoon at the Telus World of Science, watching Rocky Mountain Express in IMAX. Some of the major events that are

CSCE Edmonton YoPro committee members. / Les membres du comité « YoPro » d'Edmonton. Photo : Matthew Lui

planned for the 2013/2014 season are a Speed Mentoring session, which will give the op-

portunity for the YoPros to interact and pick the brains of some our professionals. As well, we have teamed up with "Science in the Cinemas" to present a topic related to a smaller branch of civil engineering, Biomechanical.
-- Matthew Lui, EIT, AMCSCE

If you are interested in getting involved or want more information about any of the events above, please get in touch: nparker@rjc.ca

Les jeunes professionnels à travers le pays : Région de l'Ouest

Dans ce deuxième article de notre série sur les activités des jeunes professionnels prévues ou réalisées, nous nous attardons sur les sections albertaines de la région de l'Ouest.

Calgary

Le chapitre des jeunes professionnels de Calgary collabore avec le chapitre étudiant de l'Université de Calgary au cours de l'automne. Une réception a réuni les nouveaux professionnels et les étudiants, dans un cadre intime, le soir du 25 septembre 2013. Les deux chapitres espèrent aussi organiser conjointement une visite au cours de l'année. Les plans de la section des jeunes professionnels de Calgary consistent à réunir des jeunes de différents horizons pour faire le lien avec les étudiants, qui représentent l'avenir, et de créer des relations professionnelles durables.
-- Chelsea Smolka, EIT, MASCGC

Edmonton

Pour clore la saison 2012/2013, les jeunes professionnels d'Edmonton (YoPros) ont passé un dimanche après-midi au « Telus World of Science » pour regarder « Rocky Mountain Express » en IMAX. Au nombre des principales activités prévues pour 2013/2014, mentionnons une séance de « Speed Mentoring », qui donnera l'occasion aux jeunes professionnels d'interagir et de profiter de l'expérience de certaines de nos professionnels. Nous nous sommes également associés à « Science in the Cinemas » pour exposer un sujet relié à un secteur plus restreint du génie civil, la biomécanique.
-- Matthew Lui, EIT, MASCGC

Si vous désirez participer ou si vous désirez avoir plus de renseignements sur les activités ci-dessus, adressez-vous à nparker@rjc.ca

Dr. Leslie Gordon Jaeger (1926-2013)

By Saeed Mirza, P.Eng., Ph.D., FCSCE

With great sadness, CSCE learned of the passing of past-president Leslie Gordon Jaeger, BA, MA (Cantab.), Ph.D, D.Sc., University of London, on August 20, 2013. He is survived by his wife, Kathleen, and daughters, Valerie (Michael) and Hilary (Christopher), and grandchildren Marc (Courteney) and Alexandra, niece Merrill and nephews David, Ian and Roger, and relatives and friends.

Dr. Jaeger was unique in his ability to combine applied mathematics and applied mechanics with his exceptional expertise in advanced structural analysis, earthquake engineering and highway bridge design. He used his extensive knowledge as technical editor of the Ontario Highway Bridge Design Code, and its successor the Canadian Highway Bridge Design Code. In addition, Leslie Jaeger was a brilliant researcher and an excellent professional engineer, who could visualize difficult engineering problems and find safe and sustainable solutions, demonstrating his clarity of vision and engineering skills.

After brief assignments with the Royal Navy and the University of London, Dr. Jaeger joined McGill University as a full professor in 1962. His academic career continued as dean of engineering at the University of New Brunswick, followed by senior appointments at Acadia University and the Technical University of Nova Scotia.

During his career, Dr. Jaeger was actively involved with CSCE and NSERC. He was CSCE president in 1992-93, and was chair of the NSERC Cooperative Research Opportunities Committee. He was a visionary Founding Member of ISIS, and initiator of many useful research projects for the network. He was a Fellow of the Canadian Society for Civil Engineering, Canadian Academy of Engineering, Engineering Institute of Canada, and The Royal Society of Edinburgh. Carleton University, Memorial University of Newfoundland, Technical University of Nova Scotia and Dalhousie University conferred their honorary doctorate degrees on him for his exemplary lifetime contributions to engineering and the society.

Professor Jaeger was the author or co-author of nine books and more than 180 refereed articles on earthquake engineering, advanced structural analysis and bridge design. The prestigious Gzowski and Leipholz medals are among the numerous honours and awards conferred upon him; he was also a recipient of the Order of Canada.

Dr. Jaeger's intellect, leadership qualities, sense of humour and warmth attracted graduate students from around the world. He had a rare knack for reducing complex concepts to the simplest terms, and could get students to clearly understand and apply these concepts.

Dr. Jaeger was dedicated to developing strong international exchange programs between CSCE and sister societies, especially those in developing countries. In addition, his strong ties with his former students led to his involvement in lecture tours, seminars, conferences and interesting projects in India, China and Pakistan. This interest was recognized by his appointment as honorary professor of civil engineering at Tongji University in China, and as honorary president of the Usman Institute of Technology, Pakistan.

Leslie Jaeger was an exceptional person, a daring and brilliant researcher, a truly outstanding engineer, and an exemplary and caring teacher, who was always well ahead of the times. He was a tremendous mentor and, above all, a most considerate friend to many. He will be dearly missed. ■

Hodder Avenue Underpass

An innovative bridge near Thunder Bay, Ontario, incorporates ultra-high-performance concrete in both its precast elements and field-cast connections.

By Vic Perry, FCSCE, M.A.Sc., P.Eng.
DUCTAL / LAFARGE NORTH AMERICA

The Ministry of Transportation of Ontario (MTO) has embarked on an aggressive four-laning project in northwestern Ontario that involves construction of about 30 kilometres of new highway and up to 30 structures in an area with extremely rugged terrain. Part of this project is a new "parclo" interchange that includes the recently constructed Hodder Avenue Underpass on Highway 11/17: a two-span structure that spans six lanes of traffic and is founded on a combination of hard till and bedrock. The spans, each 33.5 metres long, are supported on a centre pier and two false abutments.

Due to the location and harsh environment, the project required structural quality, superior durability and speedy construction. Aesthetics were important too since it is the first structure one encounters when approaching the City of Thunder Bay, and, considering its close proximity to the Terry Fox monument, MTO wanted an attractive structure that would complement the surrounding landscape.

To meet the requirements, the project team developed an innovative modular construction approach with extensive use of precast and ultra-high-performance concrete (UHPC). Almost all structural elements were pre-fabricated at Lafarge's plant in Winnipeg, then assembled on-site and connected with field-cast UHPC joints. (The UHPC used for this project, "Ductal," is also supplied by Lafarge.)

It is the first project in North America to incorporate a precast UHPC pier cap and stay-in-place pier column shells. The underpass also has precast high-performance concrete (HPC) box girders, abutment caps, ballast walls, sidewalks/parapet walls, slope paving panels and approach slabs. All connections were field-cast using UHPC.

Pier cap beam incorporated into superstructure

In consideration of the aesthetic requirements, a unique design concept was developed whereby the pier cap beam was incorporated into the superstructure, making it appear to be integral with the box girders and providing a frame that seems to go directly into the superstructure. This aesthetic design feature is achievable with conventional post-tensioned cast-in-place superstructures, but is extremely difficult to achieve using prefabricated elements. Other challenges were the relatively shallow superstructure in which to incorporate the main pier cap/cross beam, and the analytical complexity of two-way behaviour created by the continuous box girders intersecting the transverse cross beam. In the final configuration, the pier cap/cross beam had to become integral with the box girders and provide a continuous span between the piers and cantilever at each end.

The main pier cap was redesigned using prestressed UHPC with a characteristic design compressive strength of 150 MPa, resulting

Photos: Lafarge Canada

Completed bridge. Inset: Underside of UHPC pier column shell and pier cap.

in a total of three pier columns, instead of the four columns in the initial design using 60-MPa concrete. The pier cap is actually an inverted-T beam, embedded between two spans. This feature presented significant technical challenges because the geometry limits the T-beam's depth and cross-sectional area to only about 50% and 25%, respectively, of the average depth and cross-sectional area of conventional pier caps. The challenge was overcome by precasting the pier cap entirely with UHPC, and strengthening the pre-tensioning design to take full advantage of the ultra-high strength of the material.

T-beam prior to installation.

During the winter months, the stay-in-place UHPC pier column shells will be frequently exposed to vehicle salt sprays. Since UHPC is extremely low in porosity and has a high durability against chloride ingress, its incorporation into the pier columns results in far more durable elements. A customized UHPC shell was therefore designed to act as a non-structural form that could be filled with standard reinforced concrete on-site. In addition to their durability, the octagon-shaped UHPC shell pier columns have flared tops to enhance the structure's aesthetic appeal.

Manufacture and erection of columns

Manufacturing the column shells proved to be a challenge due to their height (8.35 m) and complex shape. Hence, they were cast on a 15-degree angle, using an inner and outer steel formwork. The material was placed slowly from the top of the column through an inlet funnel. The inner steel mould was self-collapsing to allow for initial shrinkage of the UHPC during setting.

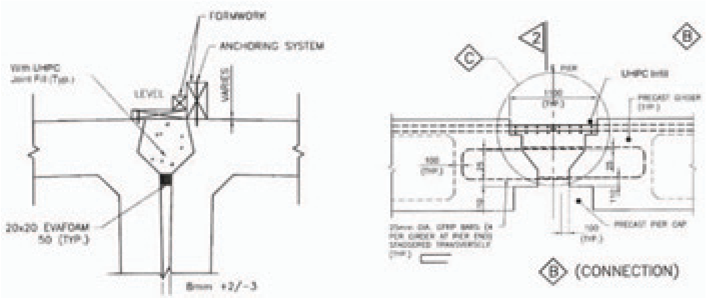
The pier column shells were erected to act as leave-in-place forms for the cast-in-place columns. To properly position them, the original steel casting forms were shipped to the site and wrapped around the precast shells before the concrete infill placement. In addition, a robust steel support structure was necessary to support the UHPC pier column shells and main pier cap until the concrete box girders had been placed. Then, the entire superstructure was made composite with the pier cap by field-casting UHPC into the connections and the robust steel support structure was removed.

Benefits in durabilty, aesthetics and construction

The Hodder Avenue Underpass used advanced concrete materials and a unique, modular construction approach in order to meet rigid design and durability requirements. When UHPC is used for both precast elements and field-cast connections, the result can be innovative, durable and aesthetically pleasing.

Ultra-high performance concrete is increasingly specified in bridge projects for field-cast connections between precast elements. By employing this technology and eliminating post-tensioning for precast elements, designers can greatly simplify the precast panel fabrication and installation processes. This simplified design provides the owner with improved tolerances, reduced risk, increased speed of construction, construction cost savings, and a more durable, longer-lasting bridge solution.

Overall, the successful completion of this project involved a strong collaborative partnership including the owner, engineer, UHPC supplier and precaster. The result is a resilient, elegant bridge structure — built to endure the harshest conditions and to still look good for years to come.



Left: formwork detail for UHPC joint. Right: UHPC joint connection.

In 2013, the Hodder Avenue Underpass project won: a Precast/Prestressed Concrete Institute (PCI) Design Award; a PCI Harry H. Edwards Industry Advancement Award; and an Ontario Concrete Award. ■

V.H. (Vic) Perry, FCSCE, M.A.Sc., P.Eng. is a former president (2010) of CSCE and currently vice-president and general manager of Ductal, Lafarge North America, based in Calgary. Email him at: ductal@lafarge.com or visit www.ductal-lafarge.com

This article is based on an article co-authored by Vic Perry: "Hodder Avenue Underpass – A New Prefabricated Bridge Solution Utilizing Ultra-High Performance Concrete," presented at the 2013 CSCE Annual Conference.

OWNER: The Ministry of Transportation of Ontario
BRIDGE DESIGN ENGINEERS: Hatch Mott MacDonald
CONTRACTOR: Teranorth Construction
UHPC SUPPLIER, TECHNICAL ASSISTANCE AND PRECASTER: Lafarge Canada

Centre photo and line drawing: HMM

North Channel Bridge Replacement

To replace a bridge that connects the city of Cornwall in Ontario to New York State, a launched-girder erection technique was used in order to minimize the environmental risks.

By Dominique Blouin, P.Eng.,
STRUCTAL-BRIDGES

The North Channel Bridge, which spans the Saint Lawrence Seaway between Canada and the U.S., connects the City of Cornwall and Cornwall Island in Ontario to the State of New York.

The Federal Bridge Corporation Limited, which owns the bridge, awarded the contract to replace the aging structure to general contractor Aecon Group Inc., who in turn selected Structal-Bridges, a division of Canam Group Inc., to fabricate and erect the new steel superstructure. The bridge design was entrusted to engineering firm McCormick Rankin, a member of MMM Group.

The new 335-metre (1,100 ft.) bridge, which will replace the existing 1962 structure, is expected to be completed in 2016. It features four spans composed of 20 box girders, each measuring 4.18 metres (13.75 ft.) wide, 3.3 metres (10.85 ft.) high and weighing a maximum of 95 Imperial tons.

Structal-Bridges' mandate included the fabrication, delivery and assembly of the structure at the erection site and the incremental launching and the leveling of the bridge on its bearings after the launch completion. Structal-Bridges was also responsible for the design and fabrication of 20 Goodco Z-Tech structural bearings composed of 12 PF-Series fixed pot bearings installed at piers 1, 2 and 3, and 8 PMG-series unidirectional pot bearings for the abutments. Structal-Bridges also performed all the engineering required to execute the launches, including the verification of structural efforts at each phase and the engineering of all launching system elements.

The 1,800 Imperial tons of steel components that form the superstructure were fabricated at the Canam Group plant in Quebec City. Structal-Bridges' expertise was brought to bear in all aspects of this project, from the complex fabrication and handling of the girders, to the transportation of the oversized components to the erection site located some 400 kilometres away.

New launching technique using counterweights

Conventional bridge building methods normally involve the construction of jetties in the water or the use of barges to support high-capacity cranes. In the case of the North Channel Bridge replacement project,


View from inside the launching nose in cantilever.


The lightweight launching nose has a sloped bottom chord to allow the girders to land on the piers without the use of lifting equipment.

Photos courtesy: Structal-Bridges

the incremental launched-girder erection technique was chosen in order to minimize the environmental risks associated with conducting operations in the channel's powerful currents. With this method, portions of the bridge components are assembled behind an abutment and pulled over the water until the structure reaches the opposite shoreline. As a result, no transitional work was performed in the river itself during the erection process. In addition, the assembly of the structure was carried out at ground level on the northern shore, thus reducing the risk of accidents and optimizing productivity at the site.

One of the particular features of the new structure is that it was erected below the existing bridge, thus limiting the amount of space available to assemble the sections prior to the launches. A temporary pier was built near the northern shoreline, at the edge of the assembly area, to be able to achieve the minimum required assembly length. To minimize structural efforts during the launches, Structal-Bridges designed a specialized launching nose weighing less than the sections themselves that was installed in front of the structure in order to pull the assemblies into place.

Given the restricted assembly area, only two box girder segments could be assembled ahead of each launch. Also, due to the sloped bottom flange of the launching nose and the horizontal bottom flange of the box girders, it was impossible to roll on the girders and launching nose simultaneously during the first two phases of the launch. To solve this problem, Structal-Bridges elaborated an exclusive technique that consists in rolling the structure and then tipping the launching nose to complete the first two increments of the launch.

This technique relies on the use of counterweights installed at the back of the assembled structure in order to undertake the first few metres of the pull. Just before the tipping point is reached (equivalent weight both behind and in front of the main support), the counterweights are removed in order to allow the assembly to touch down gently on the launching nose girders.

For the second launch, the box girder and launching nose assembly measured over 116 metres (380 ft.), and the tipping operation was performed over the water, leaving very little room to manoeuvre. It was therefore crucial to properly guide the structure so that once the assembly had touched down, the extremities of the two launching nose girders were perfectly centered on the supports.

In addition to the development of this groundbreaking technique, the simultaneous launch of two box girders required Structal-Bridges to gather data on an ongoing basis in order to validate the anticipated stress in the structure throughout the launching operations. Critical considerations, such as the reaction of supports, vertical deflection and the lateral displacement of structural elements, were continuously analyzed on site by the engineering team. Specialized systems composed of rollers and guide rails were designed and installed on each pier to limit the structure's lateral movements. The roller system was also equipped with a leveling mechanism in order to properly distribute the reactions under each box girder and ensure the adequate transfer of loads to the bridge foundations. ■

Dominique Blouin, P.Eng. is construction and business development manager with Structal-Bridges.

PROJECT: North Channel Bridge replacement, Cornwall, Ontario
OWNER: The Federal Bridge Corporation Limited
GENERAL CONTRACTOR: Aecon Group Inc.
ENGINEERING DESIGN: McCormick Rankin Corporation/MMM Group
BRIDGE FABRICATION & ERECTION: Structal-Bridges (Dominique Blouin, P.Eng.,Gaétan Losier, P.Eng., Raphaël Gagné, Jr. Eng.)
OTHER KEY PLAYERS: Roche Ltd., Consulting Group (engineering structure analysis); Montacier International (manpower at jobsite).

St. Charles River Clean-Up and Naturalization

Nick Larson, MEPP, P.Eng.

At CSCE's Annual Conference in Montreal earlier this year, the Award for Governmental Leadership in Sustainable Infrastructure was awarded to La Ville de Québec (City of Quebec) for its project to revitalize a stretch of the St. Charles River. From CSCE's perspective, sustainable infrastructure needs to consider the economic, social and environmental factors that are influenced by the project along its entire life cycle. The St. Charles River project is a premier example of how all of these factors were taken into account.

Environment: The project included the construction of retention basins that capture and store excess wastewater flows during wet weather periods. These basins allow for 95% of wastewater flows to be treated, greatly improving water quality in the St. Charles River. The project also included the naturalization of the river and shoreline to restore the natural ecosystem.

Society: The basins improved the ability to use the river for recreation activities, enhancing the historically poor appearance of the river that had been caused by the high level of pollution. However, the city also took the opportunity to construct an extensive park and trail network.

Resources: The excavated materials from the construction of the retention basins were used to produce 65,000 m^2 of wildlife habitat with natural vegetation.

Planning, decision-making and leadership: The city also took the bold step to leverage the project to revitalize the Pointe-aux-Lièvres neighbourhood. The new green space of the Parc Cartier-Brebeuf and the adjacent river has become the focal point of a vibrant community that will be a place that families can live, work and play for generations to come.

In the next issue of CIVIL we will use this column to discuss CSCE's new award guidelines that will be used in the submission process for the 2014 Award for Governmental Leadership in Sustainable Infrastructure.

The banks of the St. Charles River, before (above) and after (below)./ Berges de la rivière St-Charles (avant/après).

Clean-up of the St. Charles River, phases 2 & 3

The St. Charles is a river located in the heart of Quebec City, in one of the most ancient areas of this historic city. The objectives at the start of this project were to facilitate access to the river, to conserve the quality of the environment and to improve the quality of life for residents.

Before the project, the St. Charles River was practically an open sewer because of the state of the water. Whenever there was heavy rainfall, the rain would engorge the sewer system and the water treatment plants. Every summer, strong rains would cause between 50 and 60 overflows of the city's sewer system, which flowed towards the St. Charles River.

In order to alleviate the impact of such overflows, the most efficient and affordable solution was the construction of seven underground holding basins capable of receiving a total volume of 85,000 m^3.

These basins, as well as various other diversion works, are entirely controlled by a management system operating in real time. Based on predictive data analysed by the Csoft computer program, instructions are analysed to decide towards which basin the system should direct the wave of water building in the sewer. If necessary, the operator remotely opens or closes the floodgates strategically located throughout the system, which amounts to real-time management of the "water traffic" in order to optimize the accumulation of water.

The project was designed to control the overflow to the river, re-naturalize the banks of the river by demolishing the concrete walls in the urban section of the river, and reconstruct natural banks with provisions for wildlife habitat.

The project was budgeted at $110 million and was built within budget and according to schedule. The success of this important project can doubtless be attributed to the close cooperation of all stakeholders and to the rigid discipline of all participants.

-- Ville de Québec, submission for CSCE Award for Governmental Leadership in Sustainable Infrastructure

Le nettoyage et la naturalisation de la rivière Saint-Charles

Nick Larson, MEPP, ing.

Lors du congrès annuel de la SCGC, à Montréal, le prix pour leadership gouvernemental en matière d'infrastructures durables a été décerné à la ville de Québec pour son projet de revitalisation d'une section de la rivière Saint-Charles. Dans l'optique de la SCGC, les infrastructures durables doivent tenir compte des facteurs économiques, sociaux et environnementaux qui sont influencés par le projet tout au long de son cycle de vie. Le projet de la rivière Saint-Charles est un exemple de la façon dont ces facteurs ont été pris en considération.

L'environnement : le projet inclut la construction de bassins de rétention qui captent et entreposent les eaux usées pendant les périodes pluvieuses. Ces bassins permettent de traiter environ 95 % des eaux usées, ce qui améliore énormément la qualité de l'eau de la rivière Saint-Charles River. Le projet comporte aussi la naturalisation de la rivière et de ses rives afin de restaurer l'écosystème naturel.

La société : les bassins améliorent la capacité à utiliser la rivière à des fins de loisirs, améliorent l'apparence traditionnellement mauvaise de la rivière, causée par le haut niveau de pollution. Toutefois, la ville a également profité de l'occasion pour aménager un grand parc et un important réseau de sentiers.

Les ressources : le matériel excavé pour la construction des bassins de rétention a été utilisé pour produire 65,000 mètres carrés d'habitat pour la faune, avec une végétation naturelle.

La planification, la prise de décision et le leadership : la ville a également pris l'audacieuse décision de se servir du projet pour revitaliser le secteur Pointe-aux-Lièvres. Le nouvel espace vert du parc Cartier-Brébeuf et de la rivière adjacente est devenu le cœur d'une communauté bien vivante et deviendra un lieu apprécié où des familles pourront vivre, travailler et jouer pendant des générations.

Construction of a reservoir / Construction d'un réservoir

Dans le prochain numéro de CIVIL nous discuterons des nouveaux critères de GCSC qui seront utilisés pour l'attribution du prix pour leadership gouvernemental en matière d'infrastructures durables, en 2014.

Assainissement de la rivière Saint-Charles, phases 2 et 3

La rivière Saint-Charles est un cours d'eau situé au cœur du centre urbain de Québec dans les quartiers les plus anciens. Les objectifs de départ qui sont à l'origine de ce projet étaient de rendre l'accès à la rivière plus convivial, de préserver la qualité de l'environnement et l'amélioration de la qualité de vie des résidents.

Avant la réalisation de ce projet, la rivière Saint-Charles, en raison de l'état de ses eaux, était pratiquement un égout à ciel ouvert. Lorsqu'il pleuvait abondamment, les précipitations engorgeaient le réseau d'égouts et surtout les usines de traitement d'eau. Chaque année, en saison estivale, des épisodes de précipitations abondantes provoquaient entre 50 et 60 déversements des trop-pleins du réseau d'égouts unitaire de la ville vers la rivière Saint-Charles.

Afin de minimiser les impacts des débordements, la solution la plus

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Materials for the 21st Century

The advanced materials profiled in this issue provide new opportunities to meet engineering challenges

Dan Palermo, Ph.D., P.Eng.
CHAIR, ENGINEERING MECHANICS AND MATERIALS DIVISION, CSCE

Advances in material science and development, coupled with emerging smart materials, have provided innovative opportunities to meet new challenges for civil engineers. This edition of CIVIL features "Materials for the 21st Century." Short articles will look at the state of durability in concrete, recent advancements in fiber reinforced concretes, and emerging materials.

Although significant efforts in research have improved the quality of concrete with the objective of constructing sustainable structures, a recent case study in Quebec highlights widespread damage that was observed in concrete foundation walls. This demonstrates that concrete durability will continue to be a challenge, and that fundamental research in concrete is necessary to achieve sustainability of our structures.

Advancements in fiber and concrete technology have resulted in a new category of high performance fiber-reinforced concretes with enhanced properties. Improvements include increased compressive strength, enhanced tensile capacity and post-cracking strength, and improved ductility. In turn, these enhancements result in improved performance of structural elements and make this category of material well suited to resist extreme loading, such as seismic, blast, and impact loading.

Another interesting material that has gained traction in the research community is shape memory alloys (SMAs). This smart material has the capability to recover deformation levels that would cause yielding in traditional reinforcing and structural steels. This phenomenon provides new opportunities to develop self-centering structural elements for new construction and existing structures. ■

Dan Palermo is associate professor, Lassonde School of Engineering, York University.

Les matériaux du 21e siècle

Les matériaux avancés offrent de nouvelles possibilités

Dan Palermo, Ph.D., ing.
PRÉSIDENT, DIVISION DU GÉNIE MÉCANIQUE ET DES MATÉRIAUX, SCGC

Les avancées dans le domaine des matériaux ainsi que l'émergence de matériaux intelligents offrent des possibilités nouvelles pour relever les nouveaux défis que doit affronter le génie civil. Cette édition de CIVIL comporte l'article intitulé « Materials for the 21st Century ». De brefs articles portent sur l'état de la durabilité du béton, sur de récents progrès en matière de béton renforcé de fibre de verre, et sur les matériaux émergents.

Bien que d'importants efforts de recherche aient amélioré la qualité du béton afin de produire des charpentes durables, une récente étude de cas au Québec souligne les graves dommages observés sur des murs de fondation en béton. Ceci prouve que la durabilité du béton demeure un défi et qu'il faut encore beaucoup de recherche fondamentale pour assurer la durabilité de nos charpentes.

Les progrès en matière de technologie des fibres et des bétons ont produit une nouvelle catégorie de bétons de haute performance renforcis de fibre et présentant des propriétés améliorées. Les améliorations comportent une meilleure force compressive, une meilleure capacité de résistance à la rupture sous tension, une meilleure force après fissuration et une meilleure ductilité. À leur tour, ces progrès améliorent la performance des éléments des charpentes et font en sorte que cette catégorie de matériaux est adaptée aux charges extrêmes comme les impacts sismiques et les explosions.

Autre matériau intéressant qui suscite l'intérêt dans l'univers de la recherche : les alliages à mémoire de forme (AMF). Ce matériau intelligent a la propriété de corriger des niveaux de déformation susceptibles de causer des défaillances dans les charpentes d'acier traditionnelles. Ce phénomène présente de nouvelles possibilités de mettre au point des éléments novateurs pour les constructions nouvelles et anciennes. ■

Dan Palermo est professeur à la « Lassonde School of Engineering », à l'Université York.

Concrete in the 21st Century: Are We Still Fighting Durability Issues?

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B. Durand
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P. Rivard
UNIVERSITÉ DE SHERBROOKE, SHERBROOKE, QUE.

M. Shehata
RYERSON UNIVERSITY, TORONTO, ONT.

Recently, and despite the push towards sustainable structures with extended service life, more than 900 houses suffered damages in the concrete foundations within a short period of time after construction. This deterioration took place in the Trois-Rivières area of Québec, where the damage was observed in many cases within 3 to 5 years after construction. The damage manifested in various forms of cracking, but mainly in the form of map cracking as shown in Figure 1. In situations where the damage was severe (or because of warranty regulations), the foundation walls were demolished and replaced as shown in Figure 2.

A damage process involving the oxidation of sulphide minerals (specifically pyrrhotite) in aggregates is thought to have caused the cracking and damage to the affected concrete. Figure 3 shows an example of oxidation of an aggregate particle resulting in popout or loss of the mortar above the reacting particle. The damage was not limited to popout since the oxidation of sulphide minerals was found to cause expansion and promote sulphate attack, as will be explained later.

Concrete damage due to deleterious aggregate reactions is not new. During the 1940s, the well-known alkali-silica reaction was first reported. With the help of research carried out all over the world, preventive measures were identified and are currently used in concrete containing alkali-silica reactive aggregates. The establishment of these preventive mea-

Figure 1: Vertical and map cracking observed in foundation walls of the affected houses. The map cracks are sealed to avoid water penetration and further damage.

Figure 2: Replacement of foundation walls in severely deteriorated houses.

sures was based on a thorough understanding of the alkali-silica reaction mechanism and detailed experimental programs.

Iron sulphides, such as pyrite and pyrrhotite, are minor constituents in some rock types. These sulphide minerals are unstable in the presence of oxygen and humidity, and pyrrhotite is known as one of the most "reactive" of the sulphide minerals. Hence, under favouring conditions of relative humidity and oxygen within the concrete, the sulphide minerals in aggregate can oxidize.

The damage mechanism is believed to consist of two parts: (a) oxidation of pyrrhotite, and (b) sulphate attack. The oxidation of pyrrhotite causes an increase in volume of the aggregate particle, which can cause cracking/expansion to the concrete. In addition, the oxidation process produces sulphuric acid which is neutralized by calcium hydroxide available in concrete, forming calcium sulphate. The calcium sulphate initiates the second part of the deterioration mechanism – sulphate attack.

There are various forms of sulphate attack, including the formation of gypsum, ettringite and thaumasite, which are sulphate-bearing phases that form in concrete under sulphate attack. The formation of the above phases in hardened concrete can cause expansion and damage to the material. Moreover, the formation of thaumasite (mainly proceeding at lower temperatures) can break down the paste, causing disintegration of the concrete.

Examining concrete samples taken from the affected concrete foundations shows evidence of oxidation as well as sulphate attack. Indeed, calcium sulphate or gypsum, ettringite as well as thaumasite were clearly detected in the samples. Figures 4, 5 and 6 provide evidence of gypsum, ettringite and thaumasite formation in the affected concrete.

The reported damage triggered a collaborative research project between Laval and

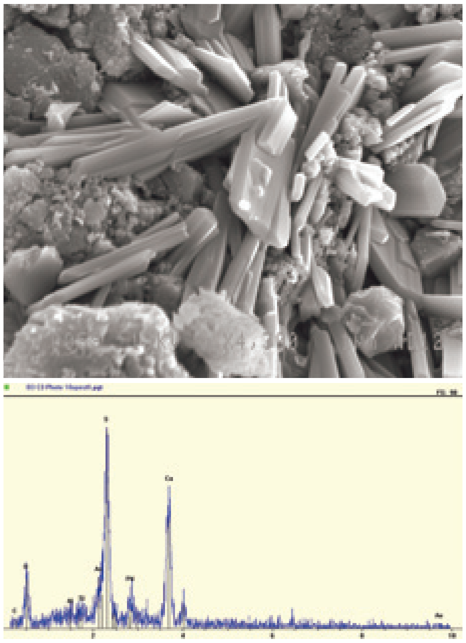

Figure 4: (a) Secondary electron images of gypsum; (b) corresponding EDS spectrum (Rodrigues et al. 2013).

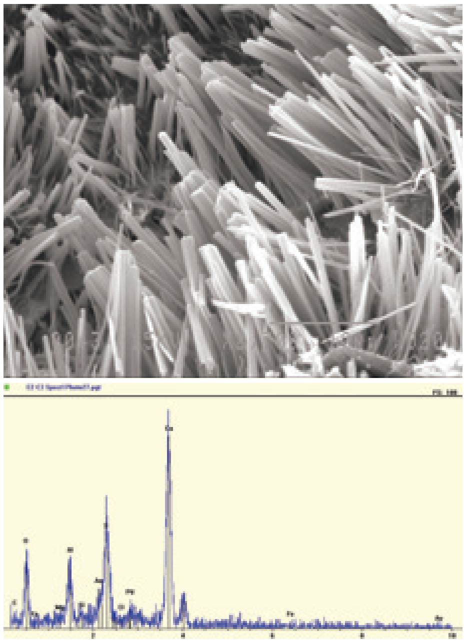

Figure 5: (a) Secondary electron images of ettringite; (b) corresponding EDS spectrum (Rodrigues et al. 2012).

Sherbrooke Universities in Québec, Hydro-Québec Research Centre in Montreal, and Ryerson University in Ontario. The research focuses on: (1) thoroughly understanding the mechanisms responsible for concrete degradation; (2) reproducing the degradation under laboratory conditions; (3) developing a performance test or a testing protocol to facilitate the identification of potentially deleterious sulphide-bearing aggregates; and (4) understanding the environmental factors and concrete properties that influence the rate and ultimate damage. Research is in progress and the outcomes will be presented through various venues.

Despite the technology and advancement in concrete materials, the deterioration described here testifies that concrete durability will remain an issue in the 21st century. Fundamental research on concrete, hydration of Portland cement and cementing materials, and interactions between the various constituents of concrete (including the aggregates) will remain a key tool to fight such durability issues and maintain the sustainability of new structures.

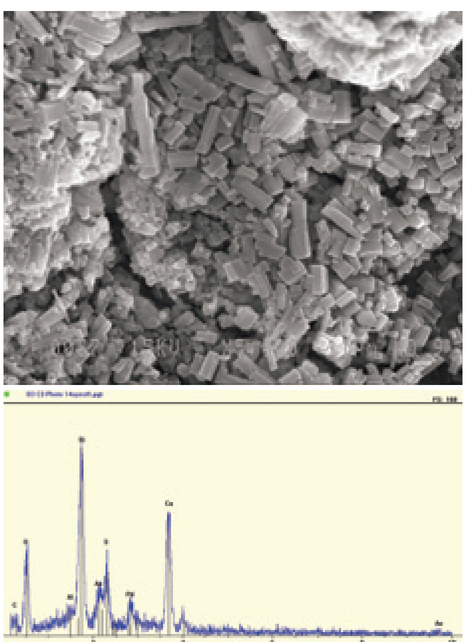

Figure 6: (a) Secondary electron images of thaumasite; (b) corresponding EDS spectrum (Rodrigues et al. 2013).

Figure 3: Oxidation of an aggregate particle resulting in popout or delamination of the mortar above the aggregate particle.

References

Rodrigues, A., Duchesne, J. and Fournier, B. (2013). "Deterioration in concrete incorporating a sulfide-bearing aggregate: petrographic characteristics and evolution of the secondary reaction products," Proceedings 14th Euroseminar on Microscopy Applied to Building Materials, 10-14 June 2013, Helsingør, Denmark.

Rodrigues, A., Duchesne, J., Fournier, B., Durand, B., Rivard, P., and Shehata, M. (2012). "Mineralogical and chemical assessment of concrete damaged by oxidation of sulphide-bearing aggregates," *Cem and Conc Res*, 42:1336-47.

High Performance Fiber-Reinforced Concretes for Improved Blast Performance of Critical Infrastructure

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Concrete is a versatile construction material that continues to be the material of choice for buildings and bridges due to availability, ease of construction, cost-effectiveness, design flexibility and aesthetic appeal. Despite its advantages, concrete's primary shortcoming lies in its weak and brittle behaviour under tensile stresses. The addition of steel fibers to a concrete matrix can transform this behaviour due to the ability of fibers to control and redistribute stresses after cracking.

When compared to traditional concrete, steel fiber-reinforced concrete (SFRC) shows several enhancements in performance, including enhanced tensile resistance, post-cracking strength, toughness and ductility. Similarly, extensive research has shown that the use of SFRC can improve the performance of reinforced concrete structural components. In beams, the addition of fibers to concrete improves diagonal tension capacity, leading to enhanced shear resistance which can promote flexural failure and ductility (Parra 2006). In columns, the use of SFRC results in enhanced core confinement leading to increased load carrying capacity and post-peak toughness (Aoude et al. 2009). Research has also shown that the use of SFRC in shear-critical members subjected to stress reversals (coupling beams, squat walls, beam-column joints, and columns) can result in enhanced ductility and seismic performance (Parra 2005).

The enhanced strain capacity, ductility and damage tolerance of fiber-reinforced concretes also makes this category of material ideal for use in the blast resistant design of structures (Banthia 2008). In the case of reinforced concrete buildings, ground-story columns must have sufficient strength and ductility in order to prevent progressive collapse. To ensure this performance, columns must be properly detailed to maintain inelastic capacity under extreme dynamic loading, resulting in highly congested sections which are difficult to construct. The use of fiber-reinforced concrete can potentially be used to relax detailing requirements, resulting in improved constructability without compromising performance.

High performance fiber-reinforced concretes for extreme load applications

Current industrial applications of SFRC have primarily focused on non-structural applications, where fibers are used at low to moderate fiber contents to replace secondary steel reinforcement. Design for structural applications and extreme loads

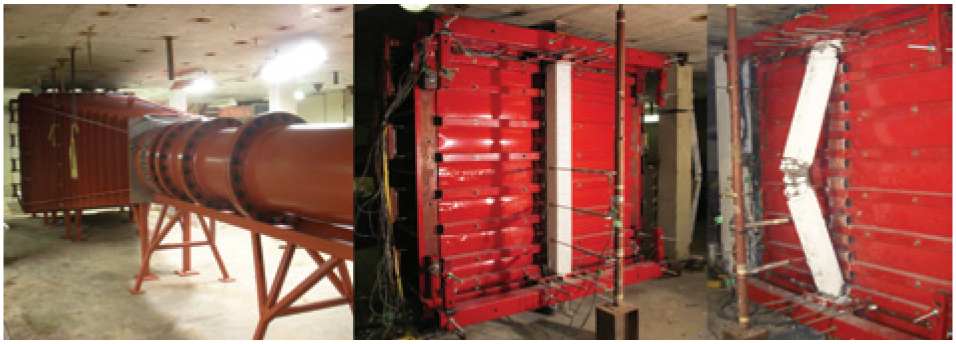


Figure 1: Blast testing of columns: University of Ottawa shock tube (left), column test setup (centre), and typical column after testing (right).

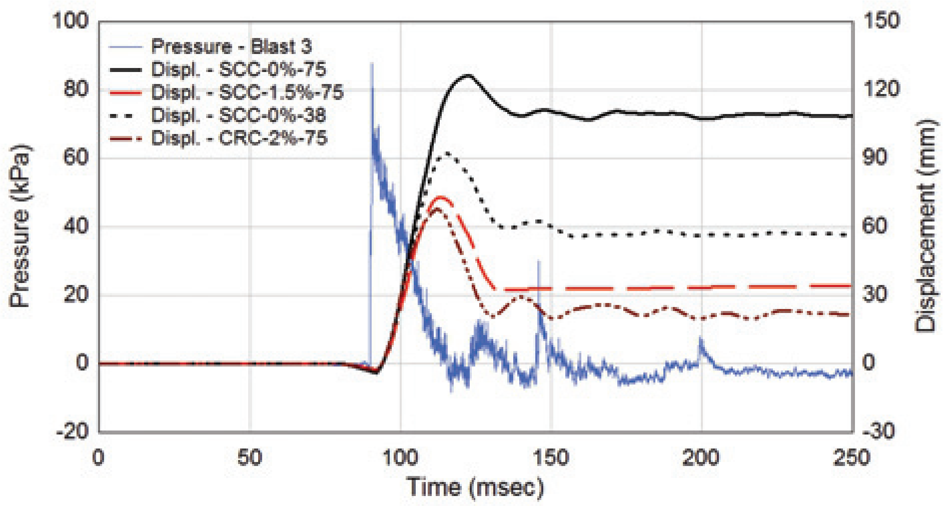


Figure 2: Pressure- and displacement-time histories for columns under "Blast 3" loading (Burrell et al. 2013a, b)

such as blast requires the use of higher fiber contents which can result in reduced workability and difficulty in concrete placement. The combined use of self-consolidating concrete (SCC) and fibers has been proposed as a solution to this problem (Khayat and Roussell 2000). The use of SCC results in highly workable fiber-reinforced concrete (HW-FRC) that can allow for ease of construction, while making possible the use of the higher fiber contents required for structural applications.

Recent advances in material science have also led to the development of a new generation of ultra high performance fiber-reinforced concretes (UHP-FRC). Through careful mix proportioning, UHP-FRC exhibits very high compressive strength, while dense particle packing ensures excellent durability and self-compacting properties. The provision of steel fibers also allows for high tensile strength and enhanced post-cracking resistance, leading to superior ductility and damage tolerance (Bindiganavile et al. 2004).

Performance of HW-FRC and UHP-FRC columns under blast loading

The structural use of high performance fiber-reinforced concretes such as HW-FRC and UHP-FRC is currently a major research thrust in the department of civil engineering at the University of Ottawa, with the primary focus being on the use of these materials in extreme load applications, such as blast. The university's blast research laboratory is equipped with a high-capacity shock tube that can simulate blast-induced shock waves without the need for live explosives. The shock tube simulates the blast wave generated by high explosives using a compression chamber that rapidly releases compressed air into an expansion chamber, where it travels along its length until it interacts with a test specimen (see Figure 1).

As part of an ongoing experimental program, HW-FRC and UHP-FRC columns have been tested under simulated blast loading using the state-of-the-art shock tube facilities at the University of Ottawa (Burrell et al. 2013a, b). The columns were 150 x 150 mm in cross-section, 2450 mm in total height, and represented half-scale first storey exterior columns in a building. The longitudinal reinforcement consisted of 4-10M bars while the transverse reinforcement consisted of 6.3 mm diameter ties having a centre-to-centre spacing of 75 mm and 38 mm, representing "non-seismic" and "seismic" detailing, respectively. The test se-

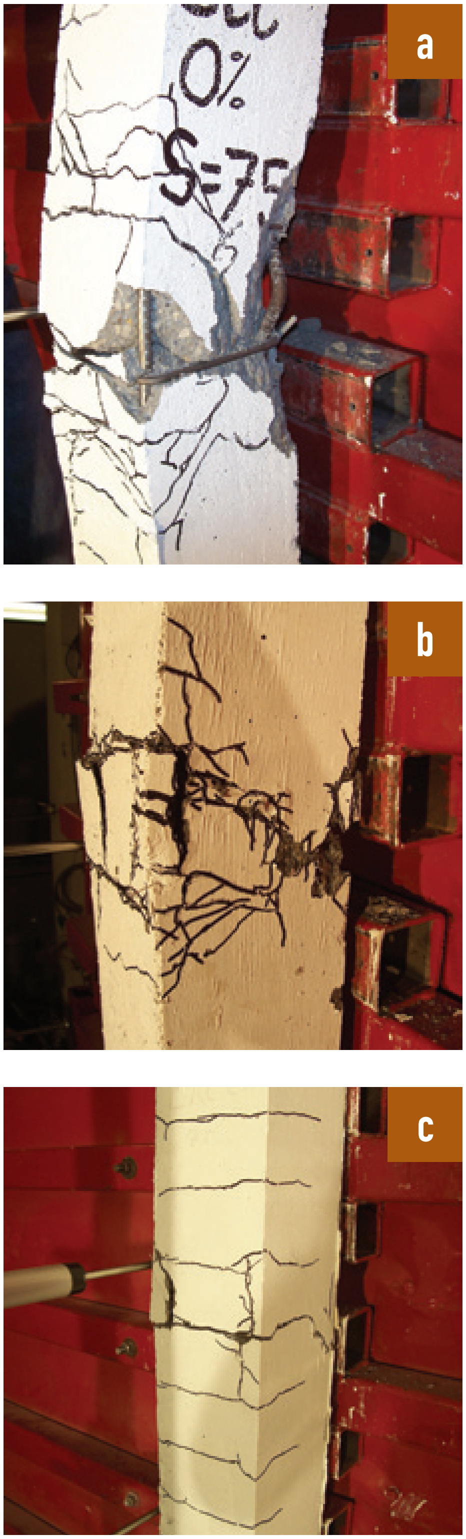
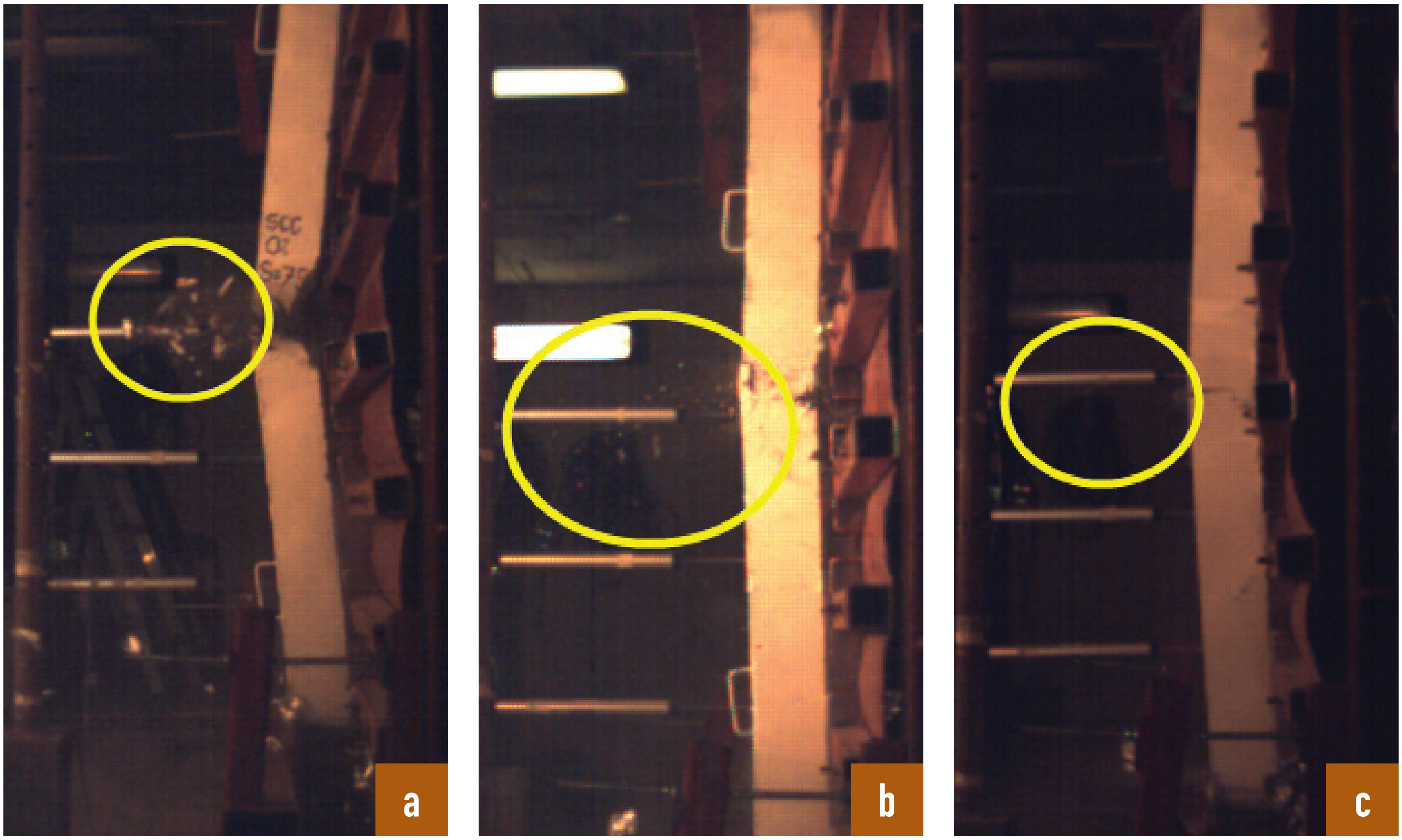


Figure 3: Damage after Blast 3: (a) SCC-0%-75; (b) SCC-1.5%; (c) CRC-2%-75 (Burrell et al. 2013a,b)



ries included plain SCC columns (having a specified compressive strength of 50 MPa), HW-FRC columns (constructed with the same SCC and hooked-end steel fibers) as well as UHP-FRC columns constructed using compact reinforced composite (CRC), a proprietary UHP-FRC having a specified compressive strength of 140 MPa and reinforced with steel micro-fibers. Some of the test results are presented later in this paper.

The specimen nomenclature reflects the three variables in the experimental program: the concrete type, the amount of fibers, and the tie spacing. Columns SCC-0%-75 and SCC-0%-38 were constructed with plain SCC (0% fibers) and hoop spacing of 75 mm and 38 mm, respectively. Columns SCC-1.5%-75 and CRC-2%-75 had non-seismic detailing (hoop spacing of 75 mm) and were constructed with SCC containing 1.5% of hooked-end steel fibers (120 kg/m^3) and CRC containing 2% micro-fibers (160 kg/m^3), respectively.

Results

The columns were exposed to different simulated blast pressure–impulse combinations using the shock-tube and aimed at testing the columns under elastic (Blast 1), yield (Blast 2), and ultimate loading conditions (Blasts 3 and 4). The average reflected impulse under Blasts 1-2-3-4 was approximately 125, 400, 750 and 900 kPa*msec, respectively. Maximum and residual displacements at the mid-span between the near fixed-end supports were measured using linear variable displacement transducers (see Figure 1). In addition, a high speed digital video camera was used to record the testing at a frame rate of 500 frames per second, and synchronized to the recorded data histories.

Figure 2 shows the midspan displacement time histories for a sample of the SCC, HW-FRC and UHP-FRC columns after loading corresponding to Blast 3. The results show that the provision of steel fibers in SCC improves blast performance. When compared to the non-seismic control specimen (column SCC-0%-75), the maximum and residual displacements are decreased for column SCC-1.5%-75. Furthermore, the column shows reduced displacements when compared to the more heavily congested seismic specimen (column SCC-0%-38). Figure 3 shows columns SCC-0%-75 and SCC-1.5%-75 after Blast 3 and illustrates the improved damage tolerance afforded by the combined use of SCC and steel fibers in the HW-FRC specimen. Figure 2 also shows the response of the companion column constructed with UHP-FRC (column CRC-2%-75).

The results demonstrate the superior blast performance of ultra-high performance fiber-reinforced concretes such as CRC. In addition to reducing maximum and residual displacements, the use of UHP-FRC allowed for superior damage tolerance (see Figure 3) and it is noted that further loading beyond Blast 4 was required to fail this column.

Figure 4 compares high-speed video stills

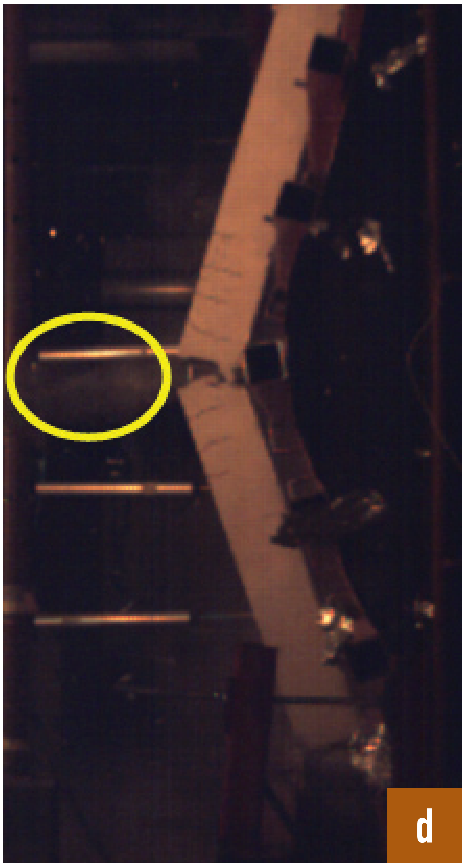


Figure 4: High-speed video stills of columns under blast loading: (a) SCC-0%-75 - Blast 3; (b) SCC-1.5%-75 - Blast 3; (c) CRC-2%-75 - Blast 3; (d) CRC-2%-75 - Blast 4 (Burrell et al. 2013a, b).

of various columns at ultimate loading conditions: SCC-0%-75 (under Blast 3), SCC-1.5%-75 (under Blast 3) and CRC-2%-75 (under Blasts 3 and 4). It is noted that while the control column shows significant fragmentation, the HW-FRC and UHP-FRC columns show minimal fragmentation, even at failure, further demonstrating the improved damage tolerance of fiber-reinforced concretes under blast loads.

Conclusions

This paper presented a summary of research that has been conducted on the structural use of high performance fiber-reinforced concretes (HW-FRC and UHP-FRC) at the University of Ottawa. A sample of results was reported for columns tested under simulated blast loading using shock tube testing. The results demonstrate that the combined use of SCC and fibers in HW-SFRC results in important performance enhancements and can potentially be used to relax detailing requirements in columns subjected to blast loads. The results also demonstrate the superior blast performance of UHP-FRC columns.

References

Aoude, H., Cook, W. D. and Mitchell, D. (2009). "Behavior of Columns Constructed with Fibers and Self-Consolidating Concrete," *ACI Structural Journal*, 106(3), 349-357.

Banthia, N. (2008) "Enhancing Impact and Blast Resistance of Concrete with Fiber Reinforcement," Resilience of Cities to Terrorist and other Threats, NATO Science for Peace and Security Series C: Environmental Security, Moscow, 171-187.

Bindiganavile, V., Banthia, N., and Aarup, B. (2002). "Impact Response of an Ultra-High Strength Cement Composite." Annual Conference of the Canadian Society for Civil Engineering, Montreal.

Burrell, R. P., Aoude, H., and Saatcioglu, M. (2013a). "Blast Behavior of Ultra High-strength CRC Columns," ACI Special Publication 293: Reinforced Concrete Columns with High-Strength Concrete and Steel Reinforcement (Paper SP 293-7), 7.1-7.18.

Burrell, R. P., Aoude, H., and Saatcioglu, M. (2013b). "Response of SFRC Columns under Blast Loads," *ASCE Journal of Structural Engineering*, submitted Sept. 2013 (paper STENG-3040).

Khayat, K.H. and Roussel, Y. (2000), "Testing and Performance of Fiber-Reinforced, Self-Consolidating Concrete," *Materials and Structures*, 33(6), 391-397.

Parra-Montesinos, G. J. (2006)."Shear Strength of Beams with Deformed Steel Fibers," *Concrete International*, 28 (11), 57-66.

Parra-Montesinos, G. J. (2005)."High Performance Fiber Reinforced Cement Composites: An Alternative for Seismic Design of Structures," *ACI Structural Journal*, 102 (5), 668-675.

SUSTAINABLE INFRASTRUCTURE | LES INFRASTRUCTURES DURABLES

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efficace et la moins coûteuse, comportait en la construction de sept réservoirs de rétention souterrains pour un volume supplémentaire d'emmagasinement de 85 000 m³.

Ces réservoirs ainsi qu'un certain nombre d'ouvrages de dérivation, sont entièrement contrôlés par un système de gestion en temps réel. En fonction de données prédictives analysées par le logiciel Csoft, des consignes sont analysées pour décider vers quel réservoir ce système doit acheminer la vague d'eau qui déferle dans le réseau. Si nécessaire, l'opérateur commande à distance l'ouverture et la fermeture des vannes placées à des endroits stratégiques, gérant ainsi le « trafic » des eaux pour optimiser l'emmagasinement.

En plus du contrôle des débordements, le projet consistait en la renaturalisation des berges de la rivière comportant la démolition des murs de béton dans la partie urbaine ainsi que la reconstruction de berges naturelles avec un habitat faunique.

Le projet d'une valeur de 110 M$ s'est réalisé selon le budget et l'échéancier prévus et sa réussite est sans aucun doute attribuable à la grande collaboration de tous les intervenants et à la rigueur de toutes les personnes qui ont participé à ce projet d'envergure.

-- Ville De Québec, résumé de la candidature pour le prix SCGC pour le leadership governemental en infrastructures durables

Pushing the Envelope in Structural Concrete Design: Applications of Superelastic Shape Memory Alloys

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Shape memory alloys (SMAs) are smart materials with the capability to return to their original shape after experiencing large strains. The medical, aerospace, automotive, and robotic industries have incorporated SMAs in various devices. More recently, SMAs have attracted the interest of the structural engineering research community. This interest has emerged primarily due to the capability of the alloy to restore to its original shape after sustaining large deformations, levels which would cause permanent deformations in conventional reinforcing and structural steels. Potential applications of SMAs include: reinforcing in concrete structures, connections in structural steel assemblies, bracing members in structures, and prestressing rods in concrete elements (Alam et al. 2007). SMAs can also be used to mitigate unseating of bridges, and to provide damping to and isolation strategies for civil structures. The focus of this article is to summarize state-of-the-art research being conducted in Canada on the use of superelastic SMAs in concrete structures.

Material behaviour

The commonly recommended form of SMAs for civil structures is nickel-titanium (NiTi), which consists of approximately 56% nickel and 44% titanium. Other forms of the alloy are also available, including iron- and copper-based SMAs. In general, SMAs exhibit two distinct crystalline phases: martensite and austenite. SMAs exist in the fully austenite phase when their temperature is above the austenite finish temperature. This phase is characterized by superelastic behaviour; the SMA returns to its original shape by simply removing the external load.

Figure 1 illustrates a typical cyclic response of an NiTi superelastic solid bar with a diameter of 12.5 mm and the behaviour of a 10M deformed reinforcing steel bar routinely used in reinforced concrete (RC) design. It is evident that the SMA bar has the capability to recover imposed strains up to 6%. Thereafter, residual strains begin to accumulate, albeit insignificant relative to the permanent straining experienced by the steel bar. The behaviour of the SMA is characterized by an initial linear elastic response in the austenite phase. This is followed by a near constant stress plateau, equivalent to yielding in steel reinforcement. This plateau is the result of stress-induced forward transformation from the austenite phase to the martensite phase in the SMA bar.

At the maximum superelastic strain where the material has fully transformed to martensite, a second linear elastic response is experienced. This initiates after 6% straining for the SMA in Figure 1. The unloading response is initially linear, followed by a lower,

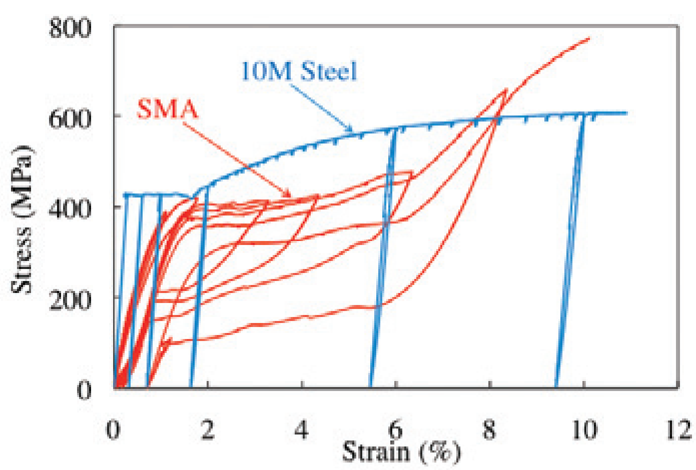

Figure 1: Cyclic stress-strain response of SMA rod and 10M deformed steel reinforcement (Abdulridha 2013).

near constant stress plateau. This phenomenon arises due to the reverse transformation from martensite back to austenite leading to recovery of the imposed strains. When the material returns to the fully austenite phase, a final linear unloading behaviour to zero stress occurs. A constitutive model applicable for modeling superelastic SMA bars was developed by Abdulridha et al. (2013). It is notable that the forward transformation stress of the SMA bar and the yield strength of steel bar are similar. An SMA reinforced member would be designed to response within the forward transformation range. Elbahy et al. (2010) proposed stress block parameters suitable for designing SMA reinforced sections.

Applications

To optimize the SMA given its higher cost relative to steel reinforcement, these materials are typically placed in the plastic hinge region and coupled to steel reinforcement outside this zone. Threaded mechanical and screw lock couplers have been used to facilitate the coupling. The latter is more practical and eliminates the need to thread the SMAs, which is a challenging task requiring carbon bits. However, slip between the SMA and screw lock coupler can arise (Alam et al. 2010).

Two examples of the successful implementation of SMAs are provided in Figures 2 and 3, showing a slender concrete shear wall and a concrete beam-column joint, respectively. In both cases, longitudinal SMA bars were placed in the critical (plastic hinge) region, at the base of the wall and at the end of the beam adjacent to the joint. The longitudinal reinforcement in the plastic hinge region in the beam-column joint consisted entirely of SMAs, while the critical section of the shear wall was reinforced with a combination of SMAs and steel reinforcement. The longitudinal SMAs were confined to the end boundary regions of the wall, while longitudinal steel reinforcement was placed in the web section. Thus, the shear wall represented a hybrid SMA-steel reinforced member. In both structural components, regular deformed steel was used for shear reinforcement, and for the anti-buckling reinforcement in the boundary elements of the shear wall.

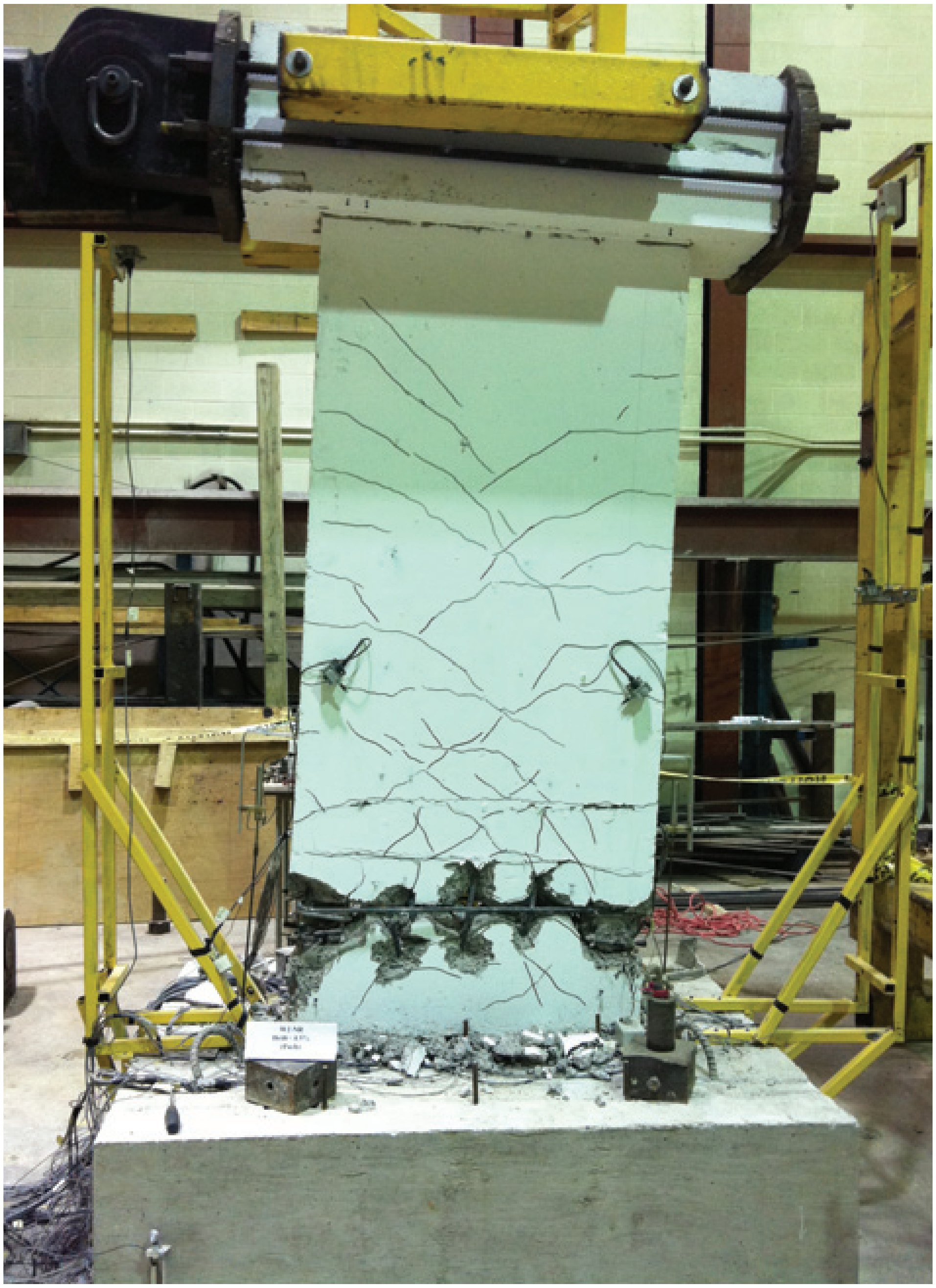

Figure 2(a): SMA shear wall (Abdulridha and Palermo 2013).

Figure 2(a) illustrates the level of damage sustained by the hybrid SMA-steel reinforced concrete shear wall, while Figure 2(b) provides the lateral load-displacement response. Figures 3(a) and (b) illustrate the condition of the SMA reinforced beam-column joint and the corresponding beam tip load-storey drift behaviour, respectively. The responses of the SMA shear wall and beam-column joint demonstrated superior recovery capacity relative to companion steel reinforced specimens. In addition, the SMA members sustained similar lateral load and lateral displacement capacities to their companion specimens. The photos illustrate that failure of the SMA reinforced components was concentrated along a major crack, which is attributed to the smooth surface of the SMA bars. This tends to promote rocking-type behaviour along the dominant crack. Both structural components demonstrated stable hysteretic response with significant energy dissipation, although less than the companion steel reinforced members. The other notable difference between the SMA and steel reinforced members is the initial stiffness; the SMA members are less stiff owing to the reduced elastic modulus of the material.

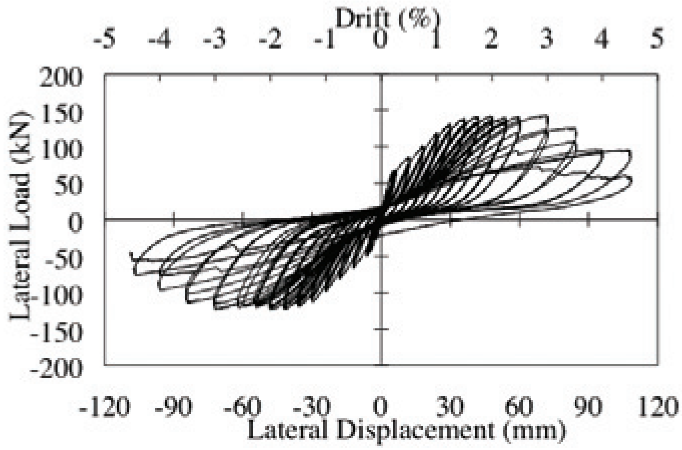

Figure 2(b): Response of SMA shear wall (Abdulridha and Palermo 2013).

Analytical models that simulate the behaviour of SMA reinforced members were developed by Alam et al. (2008), Billah and Alam (2012), and Abdulridha et al. (2013). A study by Youssef and Elfeki (2012) on full-scale frames reinforced with SMAs demonstrated that improved seismic performance is possible when using SMA bars in the beams of critical floor levels. Alam et al. (2012) demonstrated that overstrength in SMA RC frames is similar to that of steel RC frames; however, SMA RC frames possess less ductility due to its reduced stiffness.

Summary

Shape memory alloys offer the unique characteristic of recovery of high deformations after removal of load (superelasticity). This salient feature provides new opportunities for concrete structural design. The superelastic phenomenon is an attractive attribute for seismic performance, permitting the development of self-centering structural components. Large-scale experimental research has successfully demonstrated this potential in structural concrete. Analytical models that can predict the performance of SMA reinforced concrete elements have also been developed. Research of RC frame structures has also highlighted the advantages of using SMA bars in beams located on critical floor levels.

Figure 3(a): SMA beam-column joint (Youssef et al. 2008).

References

Abdulridah, A. (2013). "Performance of Superelastic Shape Memory Alloy Reinforced Concrete Elements Subjected to Monotonic and Cyclic Loading," Ph.D. thesis, Department of Civil Engineering, University of Ottawa, Canada, 346 pp.

Abdulridha, A., and Palermo, D. (2013). "Performance of a Ductile Shear Wall Reinforced with Shape Memory Alloy," fib Symposium, Tel-Aviv, Israel, CD-ROM, 4 pp.

Abdulridha, A., Palermo, D., Foo, S., and Vecchio, F.J. (2013). "Behavior and Modeling of Superelastic Shape Memory Alloy Reinforced Concrete Beams," *Engineering Structures*, 49: 893-904.

Alam, M.S., Moni, M., and Tesfamariam, S. (2012). "Seismic Overstrength and Ductility of Concrete Buildings Reinforced With Superelastic Shape Memory Alloy Rebar," *Engineering Structures*, 34(1): 8-20.

Alam, M.S., Youssef, M.A., and Nehdi, M. (2010). "Exploratory Investigation on Mechanical Anchors for Connecting SMA

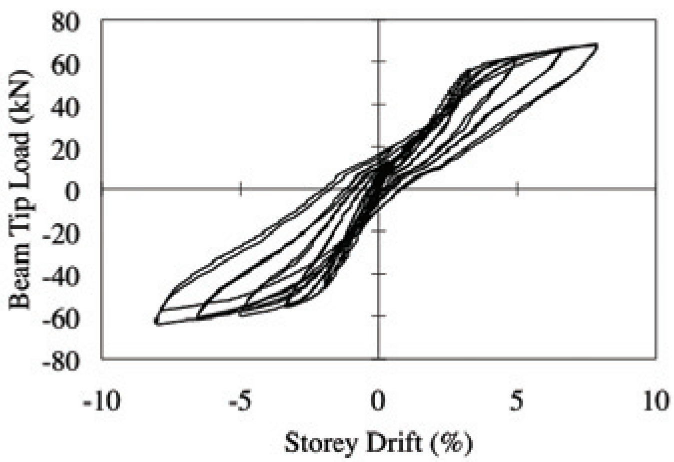

Figure 3(b): Response of SMA beam-column joint (Youssef et al. 2008).

Bars to Steel or FRP Bars," *Materials and Structures*, 43(1s): 91-107.

Alam, M.S., Youssef, M.A., and Nehdi, M. (2008). "Analytical Prediction of the Seismic Behaviour of Superelastic Shape Memory Alloy Reinforced Concrete Elements," *Engineering Structures,* 30(12): 3399-3411.

Alam, M.S., Youssef, M.A., and Nehdi, M. (2007). "Utilizing Shape Memory Alloys to Enhance the Performance and Safety of Civil Infrastructure: a Review," *Canadian Journal of Civil Engineering*, 34(9): 1075-1086.

Billah, A.H.M., and Alam, M.S. (2012). "Seismic Performance of Concrete Columns Reinforced with Hybrid Shape Memory Alloy (SMA) and Fiber Reinforced Polymer (FRP) Bars," *Construction and Building Materials,* 28(1): 730-742.

Elbahy, Y.I., Youssef, M.A., and Nehdi, M. (2009). "Stress Block Parameters for Concrete Flexural Members Reinforced with Superelastic Shape Memory Alloys," *Materials and Structures*, 42(10): 1335-1351.

Youssef, M.A., Alam, M.S., and Nehdi, M. (2008). "Experimental Investigation on the Seismic Behaviour of Beam–Column Joints Reinforced with Superelastic Shape Memory Alloys," *Journal of Earthquake Engineering*, 12: 1205–22.

Youssef, M.A., and Elfeki, M.A. (2012). "Seismic Performance of Concrete Frames Reinforced with Superelastic Shape Memory Alloys," *Smart Structures and Systems*, 9(4): 313-333.

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