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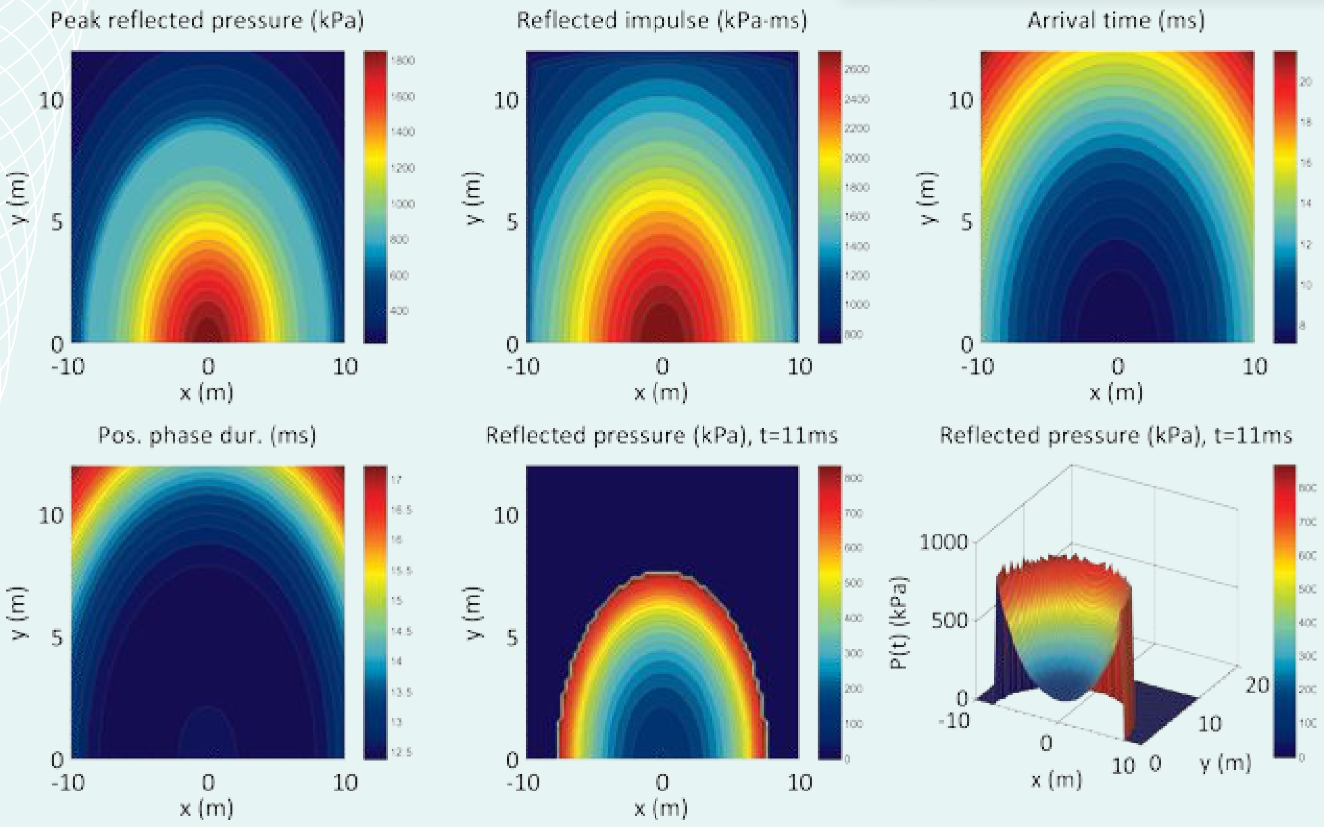

New Opportunities in Computing in Civil Engineering

Nouvelles occasions en informatique appliquée dans le domaine du génie civil

FALL / AUTOMNE
2011

28.4


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28.4

The *Canadian Civil Engineer* (CCE) ISSN 9825-7515 is published five times per year by the Canadian Society for Civil Engineering (CSCE).

***L'Ingénieur civil canadien* (ICC) ISSN 9825-7515 est publié cinq fois par année par la Société canadienne de génie civil (SCGC).**

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Annual Subscription Rates / Abonnement annuel
Canada & U.S.A. $35.00
other countries / autres pays $45.00
single copy / au numéro $7.50
agency discount / rabais aux distributeurs 10%

Design / Production
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Computing has always been a major focus area in civil engineering, with applications in environmental, structural, geotechnical, water resources, transportation and construction, among others. Computing in civil engineering has been undergoing noteworthy changes over the past 15 years or so, from both the demand or needs and the supply or capacity points of view. On the demand side, new activities related to sustainability, climate change, and health and security of civil construction have been gaining attention, which in turn demand new capacity and requirements in computing. On the supply side, recent development in information science and technology as well as in innovative materials and systems has led to advances and innovative ideas in computing applicable to civil engineering. Inevitably, new opportunities in computing are emerging from these notable changes.

The ability to innovate requires enthusiasm and knowledge, but must above all be supported by an environment that is conducive to new ideas. Such an environment allows technical creativity and innovation to flourish anywhere. Such attitude and frame of mind will allow those who adopt it to remain at the leading edge of progress and prosperity. This is exactly what CSCE's Committee for Innovation and Information Technology hopes to promote and accomplish.

This issue highlights four examples of new opportunities in computing applicable to civil engineering, namely hydrodynamics modeling, energy efficient construction, health monitoring, and blast response. All four examples illustrate not only the emerging needs and capacity in computing but also the cross-disciplinary nature of these applications.

In the case of the hydrodynamics modeling for urban and particular rural areas, the limitations of existing models have given rise to the recent development of advanced numerical urban hydrodynamic models, utilizing GIS and meteorological data, spatial and temporal information and predictive (or prediction) modeling. Attention is drawn to the contrast between conventional and innovative modeling and the relevant challenges in hydrodynamics modeling.

Environmental challenges have been the key driving force behind the recent demand for energy efficient and sustainable buildings. While considerable effort has been put into increasing the energy efficiency of the active systems such as lighting, mechanical and electrical systems and system controls, the contribution from the so-called passive systems, such as the building structure itself, is not well understood and therefore little explored. The interaction between the active and the passive systems reflects the multidisciplinary opportunities in tackling the environmental challenges.

> *Environmental challenges have been the key driving force behind the recent demand for energy efficient and sustainable buildings.*

The physical condition of a structure is by no means constant through its service life. It is imperative that its health be monitored if the structure's integrity and functionality is to be preserved during its service life. This is particularly important for structures whose onsite and continuing visual monitoring can be impractical and/or whose failures would be catastrophic and/or crucial such as dams, bridges, buried structures and pipelines. There are both challenges and opportunities in the development of smart technologies for the structural health monitoring of or in civil engineering applications.

The inclusion of blast loads to structural design is a relatively new consideration. Due to changes in functional or security requirements, many new or existing buildings are now required to resist blast loads. Both the load assessment and the structural response to blast loads are quite different from what civil engineers are used to dealing with, such as dead and live loads, wind load and even earthquake load. Weight and location of the explosives, shock waves, complex interaction between the shock waves and the structure, the pressure and impulse loads, and the local and global responses are just a few factors to be accounted for in dealing with response of structures to blast.

Canada cannot prosper in an environment of increasing world competition by merely doing what it has done in the past. We must promote innovation in order to increase our productivity.

We would like to acknowledge the Canadian Civil Engineer (CCE) for agreeing to publish a special issue on New Opportunities in Computing in Civil Engineering. We are especially grateful to the authors for their valuable contribution to this special issue. As always we welcome your comments. ■

L'informatique a toujours été un secteur important dans le domaine du génie civil, avec ses applications en matière d'environnement, de charpentes, de géotechnique, de ressources hydriques, de transport et de construction. Dans le domaine du génie civil, l'informatique a connu de profonds changements au cours des 15 dernières années, du point de vue des besoins ou de la demande, comme du point de vue de l'offre ou de la capacité. Côté demande, de nouvelles activités reliées à la durabilité, aux changements climatiques, à la santé et à la sécurité des ouvrages de génie civil ont retenu l'attention, ce qui a créé une demande pour de nouvelles capacités en matière d'informatique. Côté offre, de récents développements en matière d'informatique ainsi que de nouveaux matériaux et systèmes ont donné lieu à des progrès et à des idées novatrices en matière d'informatique appliquée au génie civil. Inévitablement, ces changements ont donné lieu à de nouvelles perspectives en informatique.

La faculté d'innover requiert de l'enthousiasme et des connaissances, mais elle doit être surtout soutenue par un milieu propice aux idées nouvelles. Cet environnement permet à la créativité technique et à l'innovation de s'épanouir partout. Cette attitude et cet état d'esprit vont permettre à ceux qui l'adoptent de rester à la fin pointe du progrès et de la prospérité. Et c'est ce que le Comité de l'innovation et de l'informatique de la SCGC compte encourager espère encourager.

Le présent numéro souligne quatre innovations en matière d'informatique applicable au génie civil, notamment en matière de modélisation hydrodynamique, d'efficacité énergétique en construction, de contrôle des systèmes, et de réaction aux explosions. Ces quatre exemples illustrent non seulement les besoins émergents et la capacité en matière d'informatique, mais aussi la nature interdisciplinaire de ces applications.

Dans le cas de la modélisation hydrodynamique pour les zones urbaines et surtout pour les zones rurales, les limites des modèles existants ont donné lieu à de récents déve-loppements de modèles hydrodynamiques numériques urbains avancés utilisant un SIG et des données météorologiques, des données spatio-temporelles, et de la modélisation prédictive. On attire votre attention sur le contraste entre la modélisation conventionnelle et la modélisation novatrice et les divers défis que soulève la modélisation hydrodynamique.

Les défis en matière d'environnement ont été à la source des dernières demandes pour des édifices durables et qui économisent l'énergie. Même si beaucoup d'efforts ont été faits pour améliorer l'efficacité énergétique des systèmes actifs comme l'éclairage, les systèmes mécaniques et électriques, et les contrôles de systèmes, la contribution des systèmes dits passifs, comme la charpente elle-même, est encore mal comprise, et donc peu étudiée. L'interaction entre les systèmes dits actifs et passifs reflète le caractère multidisciplinaire des occasions qui existent dans le domaine des défis environnementaux.

L'état physique d'une charpente ne demeure jamais constant pendant la durée de sa vie utile. Il est important de surveiller la santé de la charpente afin d'en préserver l'intégrité et la fonctionnalité pendant sa vie utile. C'est particulièrement important dans le cas des charpentes qu'il est impossible de surveiller à vue et/ou dont l'effondrement pourrait être catastrophique, comme dans le cas d'un barrage, d'un pont, d'un pipeline ou d'une charpente souterraine. Il y a à la fois des défis et des occasions dans le développement de technologies intelligentes pour la surveillante des charpentes.

L'inclusion des forces de souffle dans la conception des structures est un élément relativement nouveau. Suite à l'évolution des exigences de fonction et de sécurité, nombre d'édifices, nouveaux ou existants, doivent maintenant résister à des forces de souffle. L'évaluation de ces forces et la réaction des charpentes aux forces de souffle sont fort différentes de ce que les ingénieurs étudiaient auparavant, comme les charges mortes et les surcharges, les charges dues au vent et même les charges sismiques. Le poids et l'emplacement des explosifs, les ondes de choc, l'interaction complexe entre les ondes de choc et la charpente, les charges de pressurisation et les charges d'impulsion, et les réactions locales et globales ne sont que quelques-uns uns des facteurs dont il faut maintenant tenir compte dans l'étude des réactions aux forces de souffle.

Les défis en matière d'environnement ont été à la source des dernières demandes pour des édifices durables et qui économisent l'énergie.

Le Canada ne peut espérer prospérer face à l'accroissement soutenu de la compétition au niveau mondial en répétant ce qui se faisait dans le passé. Il nous faut donc promouvoir et encourager l'innovation pour accroître notre productivité.

Nous remercions L'Ingénieur Civil Canadien qui a bien voulu publier un numéro spécial sur les nouvelles occasions en matière d'informatique appliquée au génie civil. Nous remercions en particulier les auteurs qui ont contribué à ce numéro. Comme d'habitude, vos commentaires seront appréciés. ■

PRESIDENTIAL PERSPECTIVE / PERSPECTIVE PRÉSIDENTIELLE

RANDY PICKLE P.ENG., FCSCE – PRESIDENT@CSCE.CA

The period since my last column has been very newsworthy with respect to the state of our infrastructure. In particular, Montreal's transportation infrastructure has been the centre of attention. First, Montrealers woke up early in the summer to the news that traffic on the Champlain Bridge was being restricted due to the structural condition of the bridge. Later, the media reported that most professionals are of the opinion that the bridge, built in 1962, cannot be repaired and needs to be replaced. As a Civil Engineer, it is inconceivable that such a valuable link in the Montreal transportation network has reached the end of its life cycle after less than 50 years. One just has to look around at the other structures across the St. Lawrence, in Montreal, such as the Victoria Bridge or the Jacques Cartier Bridge, to realize what can and should be attainable. Both of these structures have been reconstructed a number of times to meet growing needs as well as to keep them functioning.

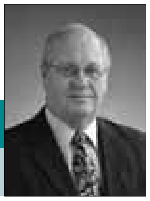
Then, as commuters in Montreal were getting accustomed to the Champlain Bridge closures, a section of the roof structure of the Ville-Marie tunnel in downtown Montreal collapsed. There are rumors and hypotheses as to why the collapse happened and we will have to wait and see what investigators determine from their findings.

These two events, and primarily the Ville-Marie collapse, have once again generated interest in the condition of the national infrastructure. Montreal is not alone in this. After the news of the tunnel collapse, an editorial in one of Toronto's dailies centered on the condition of the F. G. Gardiner Expressway though downtown Toronto. When you walk or drive under this elevated expressway, you will see a patchwork of concrete repairs. Some of those repairs were undertaken in a controlled condition by removing and replacing the deteriorated concrete, while other repairs are the result of concrete chunks falling off of the structure without warning.

These are above ground observations on the condition of our infrastructure. Our buried infrastructure is as much of a concern if not more so. There are old watermains with long histories of repairs, the continued presence of lead water services to homes, as well as sewers still serving residential areas and experiencing flooding and back-ups due to intense storm events resulting from climate change.

Unfortunately the media only seems to report on the failures. There are municipalities in this country that are managing their infrastructure extremely well to minimize the burden on the user and tax payer. For a number of years, I provided consulting engineering services to the Town of Ajax, a municipality of about 100,000 people that sprang up in the 1940's to support the war effort and has continued to grow, especially since the housing boom of the 1980's. In the early 1980's, the Town undertook to systematically improve the watermains, sewers and streets in the areas of the Town that had been in existence since the 1940's. In a matter of a little over 5 years, the average age of the Town's infrastructure was reduced significantly. The Town has continued to effectively manage its infrastructure as exhibited by the projects it carries out to maintain and enhance it without the need to reconstruct.

At the 2011 Annual General Meeting and Conference of the CSCE, in Edmonton, we will be awarding the first Leadership in Sustainable Infrastructure Award. This award is for the public sector, for towns like Ajax that are building and managing their assets with consideration of longevity, adaptability and full cost value. ■



Depuis ma dernière chronique, il a beaucoup été question de l'état de nos infrastructures dans l'actualité. Les infrastructures de transport de Montréal se sont notamment retrouvées au cœur de l'actualité. Tout d'abord, les Montréalais ont appris au début de l'été que la circulation sur le pont Champlain serait limitée à cause de l'état de la charpente. Plus tard, les médias ont signalé que la plupart des professionnels estimaient que le pont, construit en 1962, ne pouvait plus être réparé et devait être remplacé. Pour un ingénieur civil, il est inconcevable qu'un élément aussi vital de l'infrastructure des transports de Montréal ait atteint la fin de sa vie utile après moins de 50 ans. Il suffit de regarder les autres ponts qui enjambent le St-Laurent à Montréal, comme le pont Victoria ou le pont Jacques Cartier, pour voir ce que devrait être la durée de vie d'un pont. Ces deux derniers ouvrages ont été reconstruits à quelques reprises pour accommoder une circulation croissante, et ils demeurent fonctionnels.

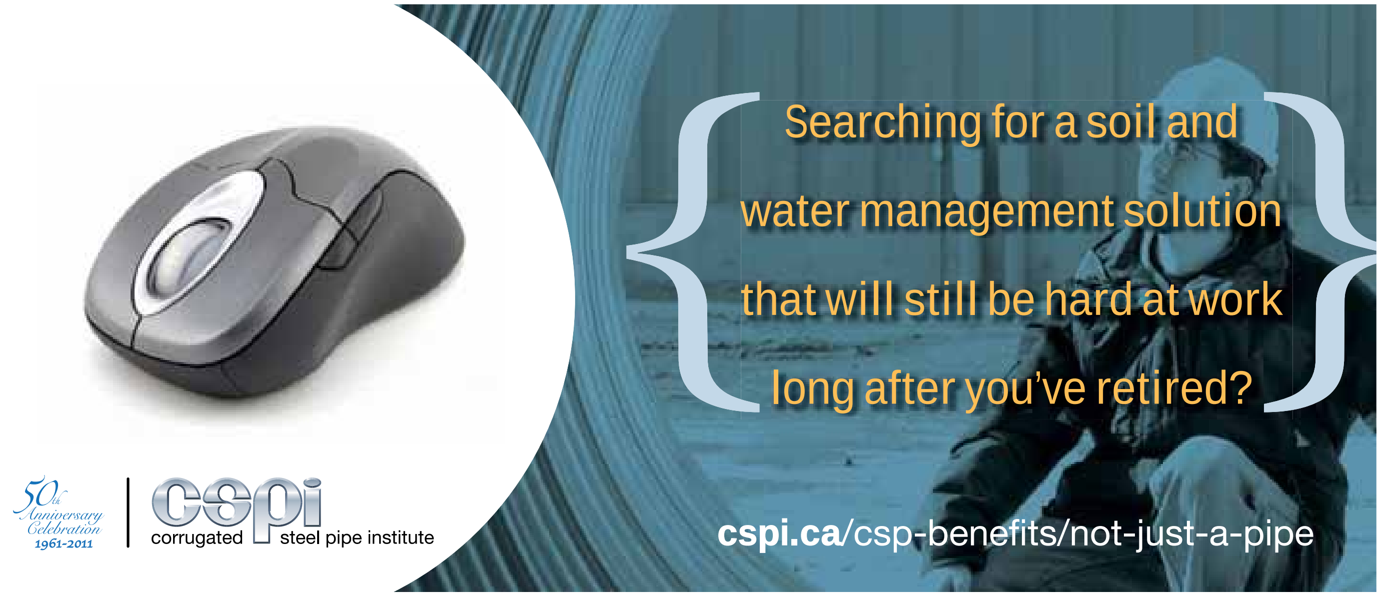
Puis, alors que les automobilistes montréalais s'habituaient aux limites imposées à la circulation sur le pont Champlain, une section du paralume du tunnel Ville-Marie s'est effondrée, en plein centre-ville. Il y a de multiples rumeurs et hypothèses sur les raisons de cet accident, et il faudra attendre le verdict des enquêteurs avant de savoir à quoi s'en tenir.

Ces deux événements, et notamment l'effondrement d'une partie du tunnel Ville-Marie, ont ranimé le débat sur l'état de nos infrastructures. Et Montréal n'est pas un cas isolé. Au lendemain de l'effondrement, un éditorial d'un quotidien de Toronto portait sur l'état de l'autoroute F. G. Gardiner, au centre-ville de Toronto. Si vous roulez ou marchez sous cette autoroute surélevée, vous verrez un assortiment de réparations en béton. Certaines de ces réparations ont été entreprises dans des circonstances bien gérées, avec l'enlèvement et le remplacement du béton endommagé, tandis que d'autres réparations ont fait suite à la chute accidentelle de morceaux de béton.

Et ce ne sont là que des observations faites à la surface de nos infrastructures. La partie enfouie de nos infrastructures est tout aussi préoccupante, sinon plus. Il existe de vieilles conduites d'eau qui ont subi maintes réparations, des tuyaux en plomb qui raccordent des maisons à l'aqueduc, des égouts qui desservent des zones résidentielles et qui subissent des refoulements lors d'orages subits attribuables aux changements climatiques.

Malheureusement, les médias semblent ne s'intéresser qu'aux échecs. Il y a dans ce pays des municipalités qui gèrent très bien leurs infrastructures de façon à minimiser le fardeau imposé aux usagers comme aux contribuables. Pendant des années, j'ai été conseiller de la ville de Ajax, une municipalité de quelque 100 000 personnes créée dans les années quarante pour appuyer l'effort de guerre et qui a continué à grandir, surtout lors du boom de la construction domiciliaire, au début des années quatre-vingt. Au début des années quatre-vingt, la ville a entrepris d'améliorer systématiquement l'aqueduc, les égouts et les rues dans les secteurs aménagés dans les années quarante. En un peu plus de 5 ans, l'âge moyen des infrastructures de la ville a sensiblement diminué. La ville a continué de géré efficacement ses infrastructures, comme en témoignent les projets réalisés pour les entretenir et les améliorer, sans avoir à les reconstruire.

Lors du congrès et de l'AGA de la SCGC de 2011, à Edmonton, nous attribuerons pour la première fois le prix pour le leadership en matière d'infrastructures durables. Ce prix est attribué au secteur public, à des villes comme Ajax, qui ont construit et entretenu leurs ouvrages en tenant compte de la longévité et de l'adaptabilité des ouvrages, ainsi que de leur coût complet. ■



ALISTAIR MACKENZIE P.ENG., FCSCE, RYERSON UNIVERSITY

Next year's Annual Conference in Edmonton will mark the 125th anniversary of the founding of the original CSCE with Thomas Coltrin Keefer as its first President.

This year, we celebrate another significant anniversary—200 years ago on January 22, 1811, Samuel Keefer, one of the most outstanding Civil Engineers in Canadian history, was born in Thorold, Ontario. Samuel was Thomas Keefer's older half brother and was to succeed him as CSCE President in 1888.

Keefer's grandfather had emigrated from Germany to America in the 1750's. As a result of his support of the royalist side during the American Revolution, the US Congress confiscated the Keefer property, and the family, led by Samuel's father George, took refuge in Canada, establishing themselves in Thorold, Ontario. There the family prospered and George became W.H. Merritt's partner in building the Welland Canal and was appointed the first President of the Welland Canal Company.

Although Samuel's early education was limited to the local country schools, this was followed by two years at Upper Canada College in Toronto where he excelled in mathematics. With this background, Samuel Keefer began his engineering career working on both the Erie and Welland Canals. He was appointed Secretary to the Board of Canal Commissioners for the improvement of the River St. Lawrence in 1833. The following year, he became assistant engineer on the Cornwall Canal and in 1839 was appointed Secretary to the Board of Works for Lower Canada. He became Canada's first Chief Engineer of Public Works in 1841.

In this capacity, he was to have a hand in most of the significant early Canadian Civil Engineering Works. These included the Beauharnois, Lachine, Ste. Anne de Bellevue and St. Ours Canals on the St. Lawrence and continuing work on the Welland Canal. In 1843–44 he designed and built the Chaudière Bridge over the Ottawa River, the first suspension bridge constructed in Canada.

In 1853 he resigned his Government position to work on the Grand Trunk Railway. In this capacity he located the railway line between Montréal and Kingston and was responsible for the hydrographic survey of the site of the Victoria Bridge which fixed its line. He also constructed the bridges over the Ottawa River at Ste. Anne de Bellevue and over the Rideau Canal at Kingston. He was also the Supervising Engineer of the Brockville to Ottawa Railway, a project which included Canada's first railway tunnel at Brockville.

He re-entered Government Service in 1857 to become Inspector of Railways and Deputy Commissioner of Public Works. In the latter capacity he was responsible for selecting the plans for the Parliament Buildings in Ottawa and for directing their construction.

In 1864 he again retired from public service but not from professional practice. In 1869 he designed and constructed the Clifton Bridge at Niagara Falls, at that time the longest single-span bridge in the world, for which he was awarded the Gold Medal at the1878 Paris Exposition. In 1872 along with Casimir Gzowski he made a survey, plans and estimates for the long proposed but never to be constructed Baie Verte Canal. (Interestingly, his obituary in the ICE Proceedings notes that this proposed canal "*has now been abandoned in favour of a ship railway over the same route*"—this, too, was to be abandoned, but CSCE recognized the pioneering and innovating engineering that went into this ship railway project by designating it a National Historic Civil Engineering Site in 1989.)

In 1880 he was appointed a member of a royal commission to inquire into the conduct and prosecution of the Canadian Pacific Railway, finally retiring due to illness in 1888. One of the most remarkable and prolific of the early Canadian Civil Engineers, Samuel Keefer died at home in Brockville on January 9, 1890. ■

Lors du prochain congrès annuel, à Edmonton, nous célébrerons le 125^{e} anniversaire de la fondation de la première SCGC, sous la présidence de Thomas Coltrin Keefer.

Cette année, nous célébrons un autre anniversaire important puisqu'il y a 200 ans, le 22 janvier 1811, naissait à Thorold, en Ontario, Samuel Keefer, l'un des plus célèbres ingénieurs civils du Canada. Samuel Keefer était le demi-frère aîné de Thomas Keefer, et devait éventuellement lui succéder à la présidence de la SCGC en 1888.

Le grand-père de Keefer avait émigré de l'Allemagne vers l'Amérique vers 1750. Comme il avait pris partie pour les royalistes lors de la révolution américaine, le Congrès américain avait confisqué la propriété des Keefer et la famille, dirigée par George Keefer, le père de Samuel, s'était réfugiée au Canada et s'était établie à Thorold, en Ontario. La famille y connut la prospérité et George Keefer devint l'associé de W.H. Merritt pour la construction du canal Welland. Il devint également le premier président de la compagnie du canal Welland.

Après avoir fréquenté les écoles locales, le jeune Samuel alla pendant deux ans à Upper Canada College, à Toronto, où il se fit remarquer par ses aptitudes en mathématique. Armé de ces connaissances, Samuel Keefer amorça sa carrière d'ingénieur en travaillant pour le canal Erie et pour le canal Welland. Il fut nommé en 1833 secrétaire du « Board of Canal Commissioners » pour l'amélioration du fleuve St-Laurent. L'année suivante, il devint ingénieur adjoint pour le canal de Cornwall, et en 1839, il était nommé secrétaire de la Commission des travaux publics du Bas Canada. En 1841, il devenait ingénieur en chef des Travaux publics pour le Canada.

En vertu de cette fonction, il participa à la plupart des premiers grands travaux de génie du Canada. Il y eut notamment les canaux de Beauharnois, Lachine, Ste-Anne-de-Bellevue et St-Ours, le long du St-Laurent, et la poursuite des travaux au canal Welland. En 1843–1844, il conçut et construisit le pont des Chaudières, sur la rivière des Outaouais, le premier pont suspendu construit au Canada.

En 1853, il quitta la fonction publique pour aller travailler au chemin de fer « Grand Trunk Railway ». À ce titre, il fixa le trajet du chemin de fer entre Montréal et Kingston et fut responsable des relevés hydrographiques qui déterminèrent l'emplacement du pont Victoria. Il construisit également les ponts sur la rivière des Outaouais, à Ste- Anne-de-Bellevue, et au-dessus du canal Rideau, à Kingston. Il fut également ingénieur surveillant du chemin de fer Brockville-Ottawa, un chantier qui comportait le premier tunnel ferroviaire du Canada, à Brockville.

Il revint à la fonction publique en 1857, lorsqu'il fut nommé inspecteur des chemins de fer et commissaire adjoint des travaux publics. Dans cette dernière fonction, il était responsable du choix des plans pour l'Hôtel du Gouvernement, à Ottawa, ainsi que de la direction des travaux de construction.

En 1864, il se retira à nouveau de la fonction publique, sans toutefois abandonner la pratique du génie. En 1869, il conçut et construisit le pont Clifton, à Niagara Falls, qui fut à l'époque le plus long pont à travée unique au monde, et pour lequel il mérita en 1878 la médaille d'or à l'Exposition de Paris. En 1872, en compagnie de Casimir Gzowski, il prépara les relevés, les plans et les évaluations du canal de la Baie Verte, qui ne fut cependant jamais construit. (Détail intéressant, sa notice nécrologique dans les actes de l'ICE mentionne que ce projet de canal « *a maintenant été abandonné pour être remplacé par un chemin de fer sur le même tracé* »—chemin de fer qui fut également abandonné. La SCGC devait cependant rendre hommage au travail de pionnier et d'innovateur que représentait ce projet de liaison rail/canal en en faisant, en 1989, un lieu historique national du génie civil.)

En 1880, il était nommé membre d'une commission royale d'enquête chargée d'enquêter sur la conduite et les poursuites possibles contre le Canadien Pacifique. La maladie le força à prendre sa retraite en 1888. L'un des plus remarquables et des plus prolifiques ingénieurs civils qui ont marqué le début de la profession au Canada, Samuel Keefer est décédé chez lui, à Brockville, le 9 janvier 1890. ■

PETER SMITH (1926–2011)

It is with great regret that the Society learned of the passing of Peter Smith, our president in 1988/89

Peter graduated in Civil Engineering from Leeds University, and worked in England before coming to Canada in 1957. He joined the Ontario Ministry of Transportation and was soon appointed Director of the Research and Development Branch, a position he held until retiring after 35 years with the Ministry. Under his leadership the Branch became recognized as among the very best in North America. Although his prime interest was in concrete, he was able to involve those within and outside the Ministry on various cooperative projects of major significance in transportation engineering.

Peter brought an intense commitment to his profession, and also to its professional societies. He was for many years an active member of the American Concrete Institute, and in 1982 was elected president, one of the very few non-Americans to be so honoured. Later he became involved with the CSCE and, following a term as chair of the International Affairs Committee, was elected CSCE president in 1988. He never gave up his participation in the work of the Society, and in 1990 became a member of the National History Committee. Here, Peter was in his element—he was a fierce advocate for the preservation of civil engineering history, and for understanding its place in our heritage.

He will be remembered as a dedicated public servant, an engineer of outstanding ability and accomplishment, and a CSCE member who served the Society with distinction.

C'est avec regret que la SCGC a appris le décès de Peter Smith, qui fut notre président en 1988/1989

Peter Smith a obtenu son diplôme d'ingénieur civil de l'Université de Leeds, et il a travaillé en Angleterre avant de venir au Canada, en 1957. Il est entré au ministère des Transports de l'Ontario, où il fut rapidement nommé directeur de la recherche et du développement, poste qu'il a occupé jusqu'à sa retraite, après 35 années de service au ministère. Sous son leadership, la direction de la recherche fut reconnue comme l'une des meilleures en Amérique du Nord. Même si le béton était son principal centre d'intérêt, il fut en mesure d'inciter les gens de l'intérieur et de l'extérieur du ministère à divers projets d'importance pour le génie des transports.

Peter Smith faisait preuve d'un profond engagement envers sa profession et ses sociétés professionnelles. Il fut pendant de nombreuses années un membre actif de l'« American Concrete Institute », et, en 1982, il en fut élu président, devenant ainsi l'un des rares non-américains à recevoir cet honneur. Plus tard, il prit du service à la SCGC. Après un mandat à la présidence du comité des affaires internationales, il fut élu à la présidence de la SCGC en 1988. Il demeura actif au sein de la SCGC, et, en 1990, il devint membre du comité national des affaires historiques. C'était son élément : il s'y fit l'avocat de la conservation de l'histoire du génie civil et de la place du génie dans notre patrimoine.

On se souviendra d'un fonctionnaire dévoué, d'un ingénieur exceptionnellement doué, et d'un membre qui a servi la SCGC avec grande distinction.

Philippe Chang PhD
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Modélisation hydrodynamique en milieu urbain : tradition, défi et innovation

RÉSUMÉ

Aujourd'hui, les modèles numériques d'écoulement en milieu urbain sont d'un intérêt tout particulier pour nos sociétés dans la mesure où la gestion des ressources en eau et la sécurité de notre environnement en dépendent. Les méthodes classiques utilisées au cours du dernier siècle demeurent d'actualité et sont encore utilisées dans la conception et l'élaboration de système, alors que plusieurs modèles hydrodynamiques d'écoulement très avancés et complets sont disponibles sur le marché. À l'exception du monde académique ou dans le cadre de projets de très grande envergure, ces modèles sont dans la pratique rarement mis en œuvre pour l'étude d'une problématique d'écoulement en milieu urbain. Cet article rappel brièvement les bases conceptuelles des modèles hydrodynamiques urbains, en identifiant les modèles les plus reconnus et discute des limites pratiques de la mise en œuvre de ces modèles.

INTRODUCTION

À mesure que s'intensifie le développement urbain et l'exode de la population vers les grands centres, la gestion équilibrée de nos ressources en eau se présente comme un défi d'importance. En milieu urbain les systèmes d'advection d'eau potable, l'évacuation des eaux de ruissellement, et l'évacuation d'eaux usées en sont les éléments clés.

En milieu urbain, les conditions spatiales du ruissellement suite à une précipitation et les niveaux d'eau associés sont altérés.

Le développement d'outils d'analyse et de modélisation de systèmes hydraulique urbain adéquats et adaptés est donc d'un grand intérêt. Évidemment cette problématique n'est pas nouvelle, on note le développement de méthodes pratiques dans l'analyse de système hydraulique et du ruissellement urbain dès le milieu du 19ième siècle. La méthode rationnelle encore utilisée aujourd'hui dans la conception de système d'égout pluvial et la méthode de Hardy-Cross comme méthode itérative pour les réseaux de distribution sont sans doute des exemples notoires.

Dans la pratique, les outils d'analyse reste de manière générale limitée et les modèles numériques sont sous utilisés. Afin de clarifier cet état de fait, nous abordons ici brièvement les particularités de l'hydrodynamique des écoulements urbains; une revue des principaux modèles dès 1960; les concepts à l'origine des modèles urbains; et enfin les difficultés d'application de ces modèles dans la pratique.

HYDRODYNAMIQUE DES ÉCOULEMENTS URBAINS

En milieu urbain, les conditions spatiales du ruissellement suite à une précipitation et les niveaux d'eau associés sont altérés. On peut remarquer une augmentation des conditions propres à l'écoulement par le biais de canaux artificiels ou naturels et la présence de voies publiques, habitations, trottoirs, remblais, et bassins. Ces facteurs augmentent le volume et la vitesse de ruissellement et sont à l'origine de l'augmentation du débit de pointe en ce qui à trait au système d'évacuation d'eau pluviale en place. La conception de structures hydriques d'évacuation et de contrôle des eaux tel que : égout pluvial, structures de diversion, bassins de rétention et réservoirs, vise à mitiger les effets adverses des débits de pointes, du ruissellement et des inondations associées. La présence de ces structures permet de réduire les débits de pointes dans le contexte d'une précipitation en permettant le transport et l'évacuation des eaux pluviales par des conduites vers l'exutoire où les effets néfastes du ruissellement (e.g. érosion et inondation) peuvent être minimisés ou contrôlés.

DÉVELOPPEMENT DES MODÈLES

Les premiers modèles numériques de drainage d'eau pluviale adaptés à des milieux urbains existent depuis la fin des années 1960. On distingue les modèles d'aide à la conception de système d'advection, les modèles prédictifs (précipitation—ruissellement), et enfin les modèles de planification et de gestion. Les premiers permettent d'optimiser la conception d'un système à partir d'une simulation hydrologique détaillée. Ainsi, cette démarche fait appel à une analyse hydrologique donnée, selon un modèle de ruissellement afin de permettre une évaluation du débit de pointe et la hauteur d'eau de ruissellement attendue. Les modèles prédictifs quant à eux sont utilisés pour valider ou vérifier la performance de structures de contrôles ou de mitigation. Cette seconde catégorie de modèles permet de simuler l'écoulement suite à une précipitation pour un système déjà existant selon des dimensions et caractéristiques connues. Enfin, les modèles de gestion sont utilisés dans le cadre d'études et de planification pour des problématiques urbaines sur de grandes régions d'intérêt et pour des périodes de temps relativement longue.

Depuis 1960, un grand nombre de modèles hydrologiques déterministes a été développé. Ces modèles peuvent incorporer la simulation d'événement singulier ou encore une simulation continue sur une longue période faisant intervenir les propriétés des sols en présence.

Les modèles commerciaux suivants sont sans doute les plus établis (Chow, 1988):

Modèle de simulation événementiel

1. *British TRRL Model*, (1962), *Transportation and Road Research Laboratory*, (Conception)
2. *Soil Conservation Service*, (1965), TR-20, *Computer program for project hydrology*
3. *Illinois State Water Survey*, (1974), ILLUDAS, *Illinois Urban drainage Area Simulator*, (Conception)
4. *U.S. Environmental Protection Agency*, (1977), SWMM, *Storm Water Management Model*, (Gestion)
5. *U.S. Army Corps of Engineers*, (1981), HEC-1, *Flood hydrograph model* et la suite HEC-2, HEC-RAS etc.

Modèle de simulation continue

1. *U.S. Army Corps of Engineers*, (1972), SSARR, *Streamflow synthesis and reservoir regulation model*
2. *U.S. Army Corps of Engineer*, (1976), STORM, *Storage Treatment Overflow Runoff Model* (Gestion)
3. *U.S. National Weather Service*, (1985), *Runoff Forecast system*

Autres modèles

1. ILSD, *Illinois Sewer Design*, (1976) (Conception)
2. WASSP *Wallingford Strom Sewer Package*, (1981) (Prédiction)
3. MITCAT,M IT *Catchment model*, (1970) (Gestion)

Les entreprises *DHI Group (DHI Water and Environement, Modeling the World of Water, MIKE Series)*; *BOSS International* (RiverCAD et WaterNetworks); et *HAESTAD (Bentley Haestad Methods WaterCAD, SewerCAD, StormCAD)* sont sans doute les plus actives dans le développement de logiciels commerciaux en hydrodynamique. Celles-ci ont su développer des modèles alliant des composantes d'analyse interreliées et de complexité adaptée propre aux problématiques d'études choisies.

CONCEPTUALISATION DES MODÈLES HYDRODYNAMIQUES URBAINS

Le concept à la base de ces différents modèles de ruissellement est issu du lien entre l'intensité d''une précipitation et la distribution de celle-ci sur un bassin versant. Cette démarche permet d'évaluer le taux maximal de ruissellement qui contribue à l'écoulement à l'exutoire. Remarquons ici que le taux maximal de ruissellement se présente comme une fraction du taux de précipitation.

D'autre part, ces modèles permettent la simulation du ruissellement résultant d'une précipitation à partir d'une représentation du bassin et de l'interrelation des composantes du système. Chaque composante modélise un aspect distinct du processus précipitation-ruissellement à l'intérieur d'une région donnée. On note par exemple comme composantes: une zone de ruissellement locale, des canaux artificiels, un égout pluvial et des réservoirs. Ces composantes sont définies par un ensemble de paramètres qui spécifient les caractéristiques propres aux différentes composantes et la relation mathématique qui permet de décrire le processus physique en cours.

Le résultat de la démarche de modélisation est la détermination d'un hydrographe de ruissellement direct pour les différentes sous régions et l'hydrographe de l'écoulement de surface en certain endroit du système. La composante de ruissellement en surface sur une région donnée est utilisée pour représenter le ruissellement de l'eau vers l'exutoire. Le degré d'infiltration et de rétention dans la région peut être déterminé ou imposé selon le cas. La ligne d'eau, fonction du débit de pointe, est donc déterminée.

Comme nous l'avons mentionné, plusieurs modèles de ruissellement sont disponibles commercialement. Ces derniers font intervenir à un degré ou un autre, les notions suivantes:

Caractérisation des précipitations

Elle est définie à partir de courbes de précipitations IDF (intensité, durée et fréquence) couramment disponibles selon une période de retour donnée. Une précipitation de référence peut également être établie.

Caractéristiques des aires drainées

Il est nécessaire d'établir un modèle numérique de terrain permettant d'établir les conditions hydrologiques de ruissellement pour la région à l'étude.

Le dimensionnement du bassin et/ou des sous-bassins, la disposition spatiale de celui-ci, ainsi que les caractéristiques géographiques du terrain et d'occupation du territoire sont déterminés. Cette caractérisation décrit la disposition et la topographie de la région à l'étude, à un degré de précision suffisant pour chaque zone de drainage de la région. Les éléments suivant sont incorporés dans la démarche :

- plan d'occupation du territoire;
- présence de ponceaux, de bassins, de fossés mitoyens et de drainage;
- voies publiques;
- cartes pédologiques de la région;
- végétation; et
- pentes du terrain.

Coefficient de ruissellement et temps de concentration

Le coefficient de ruissellement permet la détermination du temps de concentration en indiquant la proportion des eaux pluviales à atteindre le réseau d'évacuation. Ce coefficient est relié à l'imperméabilité des surfaces, notamment : les régions asphaltées, les toitures des habitations, et les pentes du terrain. Selon les conditions de précipitation, ce coefficient peut être imposé dans des conditions saturés ou non et selon le degré d'infiltration. Il peut également être imposé pour des précipitations de différentes périodes de retour et pour tout événement de précipitation sur un même bassin.

Capacité des conduites existantes

La capacité d'évacuation maximale des conduites et des grilles d'égouts peut être évaluée selon leur dimensionnement à pleine capacité, généralement en écoulement gravitaire

ADAPTATION PRATIQUE DES MODÈLES

Comme nous l'avons mentionné précédemment, malgré la disponibilité de plusieurs modèles et leurs caractéristiques très avancées, il demeure que dans la pratique les méthodes traditionnelles reconnues sont généralement utilisées. Dans certains cas, on envisage à partir de ces approches classiques, des méthodes d'optimisation plus avancées quoique de mise en œuvre toujours facile.

Ainsi, la mise en œuvre de la méthode rationnelle est sans doute l'exemple le plus remarquable. Après plus d'un siècle d'existence et malgré l'apparition de nombreux modèles numériques raffinés et de plusieurs critiques à son endroit, cette méthode est sans doute la plus utilisée encore aujourd'hui. Les modèles numériques actuels présentent pourtant des avantages évidents. Il faut cependant reconnaitre la simplicité et l'élégance des méthodes traditionnelles.

D'autre part, la mise en œuvre de modèles numériques en milieux urbains requière un degré d'entrant en qualité et en quantité très significatif. On parle ici de données numériques de terrains et de données pédologiques très détaillées, disponible à partir de système d'information géographique (SIG), particulièrement important en milieu urbain. En l'absence de ce niveau de détails, il demeure que les modèles et les résultats d'analyse obtenus ne sauraient être plus précis que les données spatiales ou les conditions initiales établies. Peu de municipalités ou villes sont généralement capables de fournir ce genre d'information à un degré suffisant pour justifier l'utilisation de modèles avancés. Dans le cas de système déjà en opérations ou de question de contrôle, remarquons qu'on ne saurait être plus précis qu'en déterminant directement à l'exutoire l'hydrographe en cause. Il faut aussi reconnaitre que dans la pratique un nombre assez limité de scénario peut généralement être vérifié, et la flexibilité que pourraient offrir les modèles numériques perd donc de son intérêt à moins d'entreprendre un travail de très grande envergure.

Malgré l'utilisation de cette méthode qui peut apparaitre dépassée, il devient assez aisé avec un effort minimal, de vérifier un concept final par une étude hydraulique mettant en œuvre des simulations multiples et une analyse de coûts et ce pour un risque minimal. En d'autres mots, une fois la conception initiale envisagée par une méthode classique, la validité du système peut être vérifiée dans un deuxième temps à l'aide d'une étude dynamique d'un hydrogramme d'écoulement pour l'ensemble du système. Cette approche était d'ailleurs recommandée dans *Wallingford Storm Sewer Package* (WASSP, Price 1981).

Il faut également reconnaitre que l'élaboration d'un système de réseau de conduites dans le contexte spécifique d'une ville fait intervenir un jugement assez subjectif qui demeure non négligeable dans le processus de conception. Encore une fois, les modèles numériques complexes perdent de leur intérêt dans ce contexte.

INNOVATION

Il devient donc important de s'interroger sur l'utilisation de ces modèles numériques afin de permettre leur exploitation de manière efficace au quotidien en l'absence d'entrants adaptés et adéquats. Dans la mesure où l'influence des paramètres d'analyse peut être établie avec précision dans la modélisation, une tolérance acceptable sur les résultats peut être envisagée, permettant ainsi une utilisation convenable de ces modèles. De plus l'examen et l'obtention des données les plus influentes pourraient être priorisés davantage au détriment des autres, permettant une utilisation judicieuse des ressources d'acquisition limitées. Il convient d'admettre que cette démarche d'analyse va au-delà d'une étude de sensibilité des paramètres du modèle, mais se centre plutôt dans une perspective d'un équilibre acceptable: coût des données/ressources engagées-influence des paramètres du modèle-bénéfices encourus sur le résultat d'analyse. Cette quantification des modèles n'est pas usuelle en industrie et demeure plutôt du domaine de l'exercice académique. Elle demeure pourtant clé dans la justification des options d'analyse pour les services publiques et l'industrie et dans l'utilisation de ces modèles dans le cadre d'applications courantes. Évidemment ce genre d'évaluation prédictive ne peut être envisagée que par les entreprises à l'origine du développement des modèles. Celles-ci doivent permettre à l'utilisateur-client de reconnaitre dans l'utilisation du modèle, les avantages anticipés par rapport aux ressources investis dans la démarche en elle-même.

CONCLUSION

Il apparaît que les ressources qui permettraient la mise en place de manière efficace de modèles numériques détaillés en milieu urbain dépassent largement nos besoins dans la pratique quotidienne de l'hydraulique urbaine. Ainsi, la mise en place de tels modèles requière des investissements importants, particulièrement au niveau de système d'information géographique et de données météorologiques. Les informations géospatiales et temporelles dans un format adapté, à une échelle détaillée en quantité et de qualité suffisante, ne sont pas encore largement disponibles dans les grands centres et certainement pas en région plus rurale. Cet état de fait ne permet pas d'envisager donc une modélisation numérique adaptée, capable d'apporter des réponses plus précises, plus justes, de manière plus rapides et ayant plus de flexibilité que les méthodes d'évaluations traditionnelles certes « rudimentaires », mais cependant bien établis. L'information étendue qui serait alors disponible ne justifie pas le coût incident, alors que des approches plus traditionnelles pourraient fournir assez efficacement, l'essentiel de l'information en cause. Dans la mesure où la mise en œuvre d'outils avancés de modélisation permet d'apporter un supplément d'information à certaines problématiques en hydrodynamique urbaine, il demeure que leur efficacité peut être mise en cause. Une quantification de ces modèles au sens d'une évaluation prédictive des données disponibles par rapport aux paramètres d'analyse et des résultats escomptés pourrait sans doute justifier plus efficacement leur utilisation dans le cadre d'applications courantes. ■

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Decreasing Environmental Impact of Buildings Through Innovative Technologies

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Buildings are like living organisms: they consume energy and produce waste. Approximately 40% of the total energy produced in North America is consumed by residential and commercial buildings [1,2]. Around 45% of carbon dioxide emissions in the U.S. originate from buildings. In the U.K., domestic energy use has been reported to account for around 60% of carbon emissions [3]. Additional greenhouse gas emissions and energy usage result from the manufacture and transportation of building materials and products as well as from the demolition of old buildings [4].

Today's economic and environmental challenges have compelled building owners, developers, engineers, architects and policy makers to reflect on these figures more carefully than before and to come up with less energy consumption alternatives. One such alternative that has emerged is the concept of the net-zero energy building—a commercially viable building that uses zero net energy and is carbon neutral. In a typical commercial building, over 80% of total energy consumption can be attributed to heating, cooling and lighting, as shown in Table 1. Therefore, the net-zero energy building concept implies that the energy **demand** for heating, cooling and lighting is reduced by active and passive methods, and this reduced demand is met on an annual basis from a renewable energy supply that is typically integrated into the building design. The concept also requires that the power grid is used to **supply** electrical power when there is no renewable source available, and the building will export power to the grid when its power production exceeds its demand.

Although the net-zero energy building concept is not new, its implementation has been few and far apart. The main reason behind this lag is the complex nature and location-specific requirements of buildings—not unlike most living organisms. The focus of this article is on the energy demand side of the net zero energy equation, i.e. how to reduce the energy demand of a building through the use of innovative active and passive technologies. In this article, a number of innovative passive techniques that are designed to decrease the environmental impact of buildings are reviewed.

PEAK ENERGY LOAD REDUCTION AND SHIFTING USING THERMAL MASS OF BUILDINGS

A technique that has been receiving renewed attention in recent years utilizes the thermal mass of buildings to reduce and shift their peak energy loads/demand. Thermal mass is the capacity of a material to store heat. Concrete or masonry has a higher heat storage capacity than air; therefore, there is significant potential in using the natural thermal mass of buildings to reduce and to shift peak load energy demands. For example, in winter, due to their mass, buildings can absorb heat from sunlight either directly or by means of heat pumps; at night the process is reversed as heated mass gives up its stored heat, warming the building by radiation, convection and conduction. During summer months, the part of the mass that is properly shaded can absorb the heat from air in the building and reduce the active HVAC requirements. Figure 1, prepared by the Concrete Centre in UK [6], demonstrates that proper use of thermal mass of buildings can reduce and shift peak energy load requirements by regulating internal air temperature.

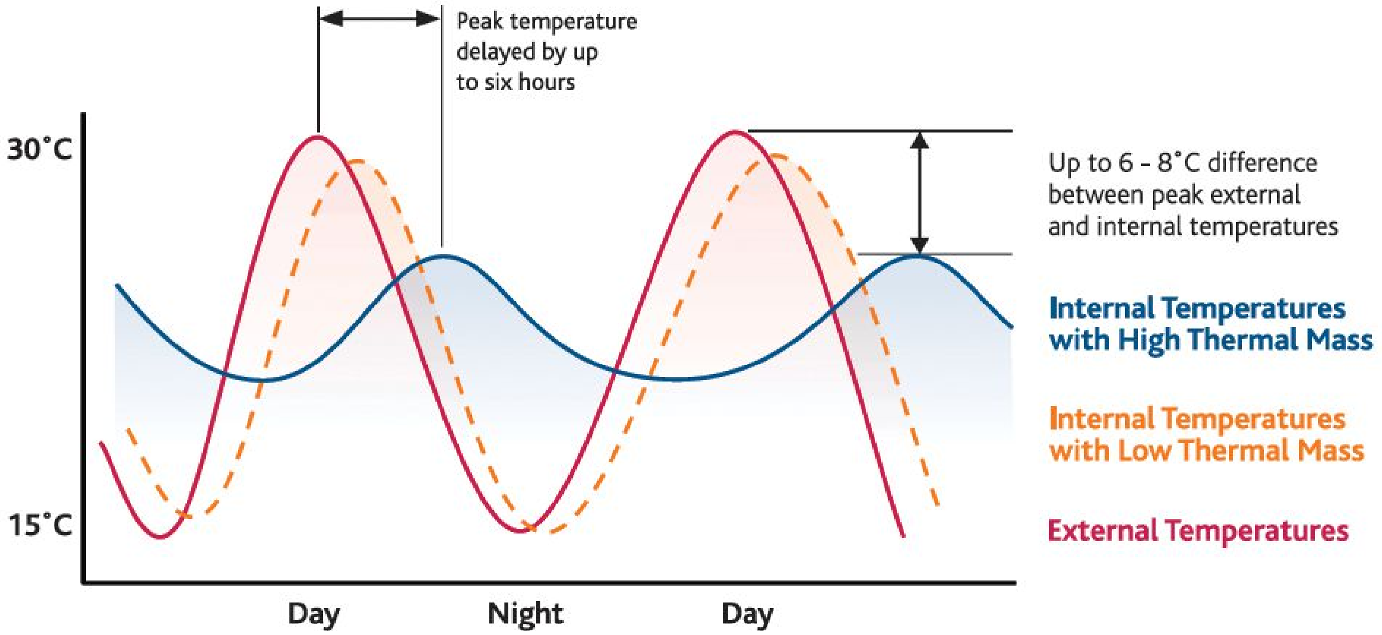

FIGURE 1: Peak load reduction and shifting of buildings by proper use of thermal mass. (Source: The Concrete Centre, Surrey, UK. [6])

Most commercial buildings have adequate thermal mass (e.g. as concrete slabs or masonry walls) that can be utilized to reduce and shift peak energy load. In particular, hollow core slabs that utilize air passing through the slabs to transfer heat in and out of concrete, have significant potential for this purpose. In the winter months, for example, the air that is heated using natural sunlight through solar panels can be circulated through the ducts of the hollow concrete slab to transfer energy to the thermal mass of concrete for storage and its subsequent release to reduce the heating requirements during the evening. Commercial applications of hollow core slabs that use this idea have already been in the market; Figure 2 presents such a commercial implementation [7].

Figure 3 illustrates the average slab surface temperatures obtained from a numerical study carried out on a 4 m × 6 m hollow core concrete slab with 150 mm thickness. It was assumed that the building's HVAC system had a minimum thermostat setting of 16°C and the forced heated air flow in the ducts of the hollow core slab started at 7 A.M. and ended at 4 P.M. It can be seen in Figure 3 that the average surface temperature of the slab increases as much as 10°C between 7 A.M. and 4 P.M. while providing a comfortable working environment during the operational hours of the office. During the evening hours, the thermal energy stored in the concrete slab is used to provide continuous heat to the room while reducing the demand for building's HVAC system to keep the room above 16°C. Literature review of and information on a current investigation on the effects of thermal mass on energy performance of buildings with a focus on peak load reduction and shifting can be found in [8].

Table 1: Energy usage in commercial/institutional buildings in Canada	
Space Heating	54.3%
Water Heating	7.9%
Lighting	13.2%
Space Cooling	3.5%
Auxiliary Equipment/Motors	20%

(Source: Energy Use Data Handbook (NRCAN, 2006 Data [5])

UNGLAZED TRANSPIRED SOLAR COLLECTORS

Unglazed transpired solar collectors use energy from sunlight to preheat ventilation air as it is drawn into a building [9,10]. In a typical system, a dark perforated metal wall is installed on the sun-facing side of a building at a small distance from the building's structural wall, as illustrated in Figure 4. The perforated wall converts solar radiation to heat. Building's ventilation fans mounted at the top of the wall draw outside air through the perforations of the transpired collector, transferring the thermal energy to the air passing through the holes. The warmed air is then distributed to the rooms of the building through the existing ventilation system. By preheating outdoor air with solar energy, the technology removes a substantial load from a building's conventional heating system. The technology is ideally suited for buildings with at least moderate ventilation requirements in sunny locations with long heating seasons [10].

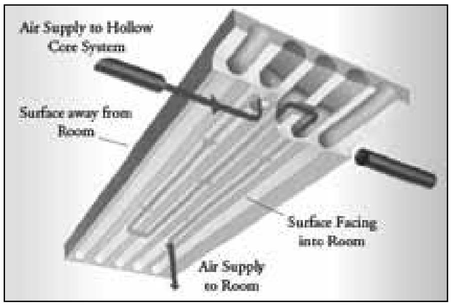

FIGURE 2: Application of a hollow-core slab system to increase energy efficiency of buildings. (Source: Termodeck International Ltd. [7])

SOLAR CHIMNEYS

Solar chimneys have been used for centuries to improve the natural ventilation of buildings by using convection of air heated by passive solar energy. In its simplest form, a solar chimney is a vertical shaft utilizing solar energy to enhance the natural stack ventilation through a building. In modern forms, solar chimneys may be composed of a glazing plate that collects the solar radiation and a storage wall that absorbs the

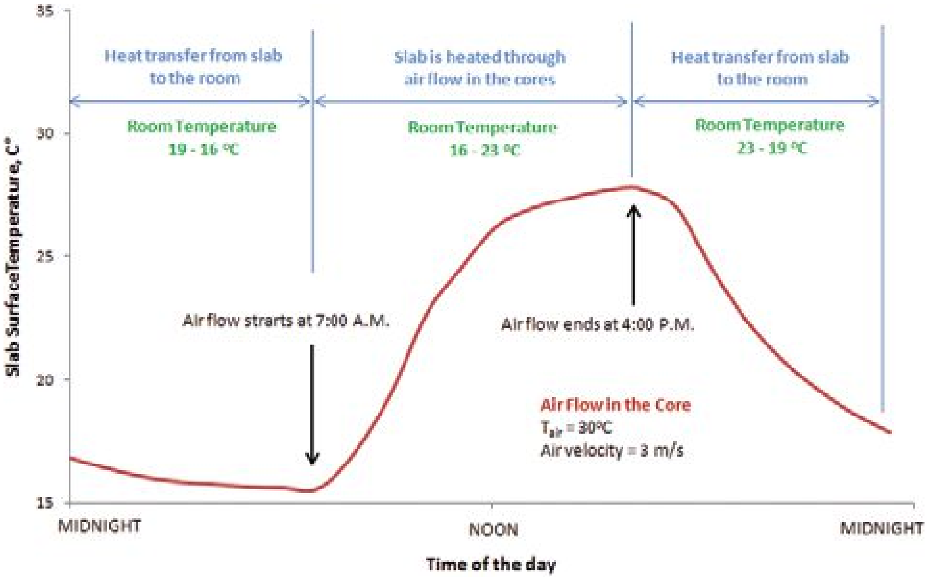

FIGURE 3: The change slab surface temperature during the operation of a hollow core slab with forced heated air system [8].

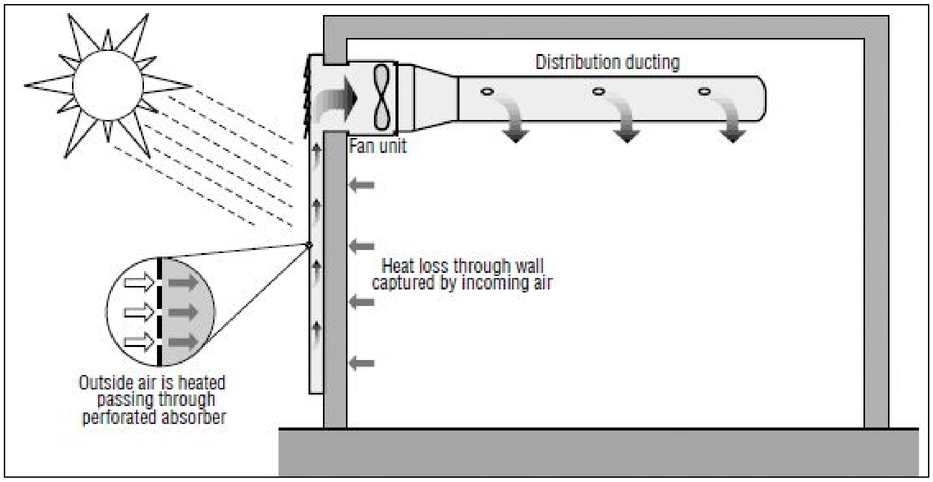

FIGURE 4: Winter use of unglazed transpired solar collectors to increase energy efficiency of buildings. (Source: U.S. Federal Energy Management Program [10])

energy (Chantawong et al., 2006). During the day, solar energy heats the chimney and the air within it, creating an updraft of air in the chimney. The suction created at the chimney's base can be used to ventilate and cool the building below. There are, however, a number of solar chimney variations, as illustrated in Figure 5.

TROMBE WALLS

A Trombe wall is a sun-facing wall acting as a thermal mass separated from the outside by glazing and an air space, designed to absorb solar energy so that it is released selectively towards the interior at night. In modern Trombe walls, or Solar Air Flow systems as illustrated in Figure 6, there are also vents at the top and bottom of the air gap between the glazing and the thermal mass [12]. Heated air flows via convection into the building interior. The vents have one-way flaps which prevent convection at night. By changing the configuration slightly and allowing fresh air from outside to enter at the bottom of the wall, the Trombe wall can pre-heat the cold fresh air before it enters the building proper. In the summer months, the airflow configuration can be changed so that inside air is drawn in from the bottom vents and exhausted out to the atmosphere, acting the same way as a solar chimney, inducing natural ventilation within the building. Literature review of and information on a current investigation on the use of Solar Airflow Window systems to achieve energy saving can be found in [13,14].

SUMMARY

Common practices such as applying proper insulation, providing a tight building envelope, installing and maintaining high efficiency windows and doors have been known to reduce considerably the energy demand and environmental impact of buildings. Innovative architectural practices that place and orient windows, doors and other building openings to maximize the use of natural light and ventilation and that use proper shading techniques have also been shown to make significant contributions to building efficiency. This article presented some of the innovative passive technologies that can be utilized to reduce the energy demand and therefore the environmental impact of commercial or residential buildings in support of the net-zero energy goal. ■

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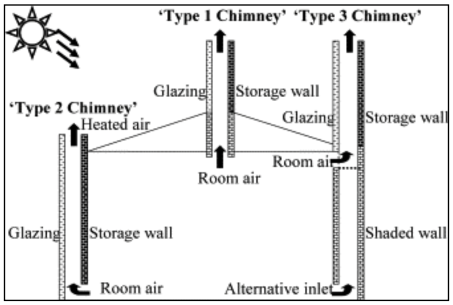

FIGURE 5: Different configurations of solar chimneys in a building [11].

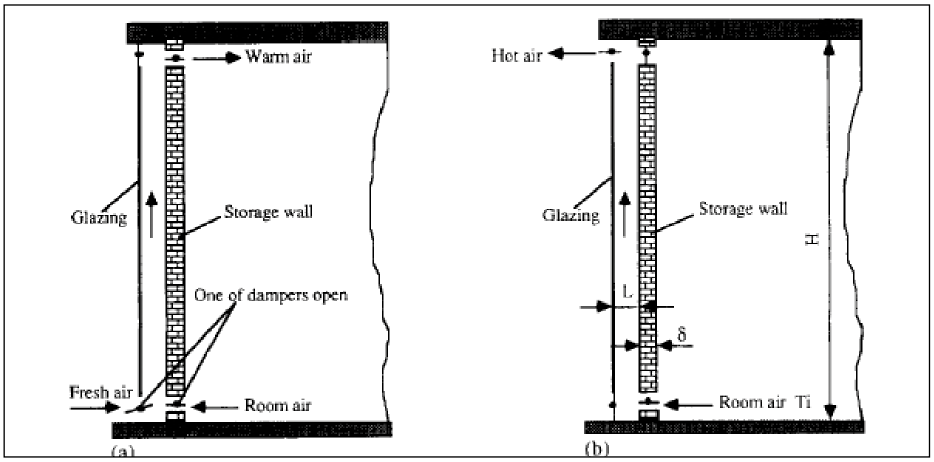

FIGURE 6: Different configurations of Trombe wall in (a) summer (b) winter [12].

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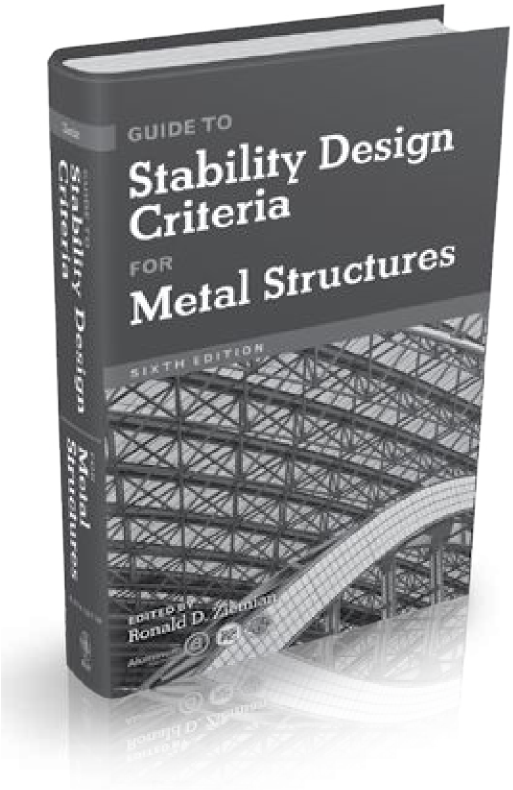

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Smart Technologies and Structural Health Monitoring for Civil Engineering*

INTRODUCTION

Knowing the health condition of structures is imperative to preserve their integrity and functionality during their service life. Structural Health Monitoring (SHM) is the process of monitoring the in-situ behaviour of a structure accurately and efficiently, assessing its performance under various service loads, detecting damage or deterioration, and determining the health or condition of the structure. This is particularly useful for monitoring large infrastructure systems, such as dams, bridges, and historical buildings as well as buried structures and pipelines where the control of the performance is crucial but onsite visual monitoring could be difficult if not impossible. If actuators are added to the structure to react, adapt and adjust its response to the applied solicitations, the structure is then called a smart structure or system. By incorporating smart materials, remote sensing and actuation as well as computer based knowledge systems, a smart structure provides engineers with information on how structures are performing over time. SHM could be considered the first step in achieving a smart structure.

DEFINITION

The field of smart technologies encompasses smart materials, smart structures

and smart systems. A smart system is a non-biological structure imitating biological pattern of functioning in order to achieve a specific purpose. The basic five components and their equivalents in the human body has been defined by Akhras [1] as follows (Fig. 1):

1. Data acquisition (*tactile sensing*): use sensors to collect the raw data;
2. Data transmission (*sensation nerves*): forwards the raw data to the local and/or central command and control units;
3. Command and Control centre (*brain*): manages and controls the whole system by analysing the data, reaching the appropriate conclusion, and determining the required actions;
4. Data instructions (*motion nerves*): transmit the decisions and the associated instructions back to the members; and
5. Action devices (*muscles*): take action by triggering the controlling device/units.

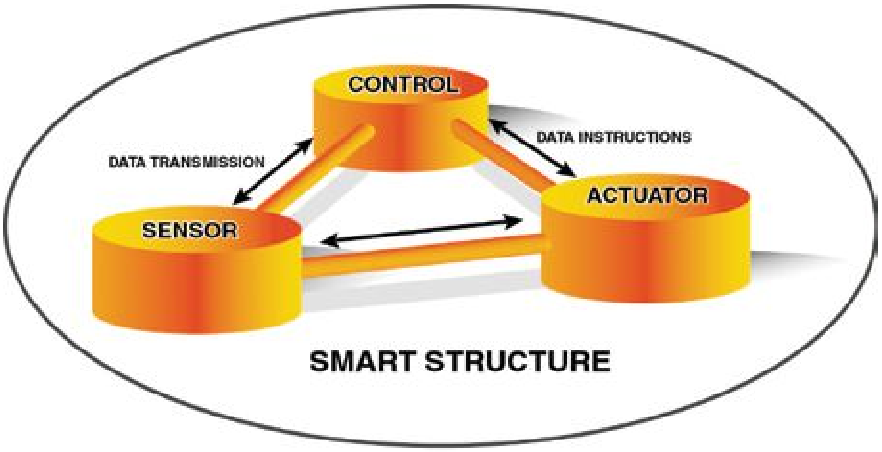

FIGURE 1: The basic five components of a smart structure.

BACKGROUND

The field of SHM & Smart Structure continues to see advancements in research although its application in civil infrastructures remains largely done by research organizations and for multi-million dollar projects. The most frequently thought of use for monitoring systems is in bridges, especially with the media attention regarding the recent bridge collapse in Minneapolis, Minnesota. Testing has largely been centered around bridges as well. Recent growth in the industry of fibre optics, combined with ongoing research in the field of actuation and computing has enabled more widespread use of these smart systems. However, there are still many challenges in bringing SHM and smart structures into common practice. Due to space limitations, this paper will only deal with the sensing component of a smart system which is the SHM.

CHALLENGES & REQUIREMENTS

The SHM system should be able to provide real-time, reliable information pertaining to the safety and integrity of a structure. The immediacy and sensitivity of SHM can allow for short-term verification of innovative designs, early detection of problems, avoidance of catastrophic failures, more effective allocation of resources, and reduced service disruptions and maintenance costs. SHM systems can be installed during construction by incorporating the sensors into the structure, or years afterward. Within the civil industries, the need for reliable SHM is great. Structures are often required to be operational 24 hours a day in order to recover their start-up and operational costs or to provide a critical service to the community. The capability to perform prognostic and preventative maintenance through SHM has been shown to have a significant impact on operational availability and life-cycle cost by reducing inspection and maintenance. Built-in SHM systems can supplement, and in time, potentially replace visual inspection.

The incorporation of an SHM system into civil engineering application has basically the following benefits:

1. Acquiring up-to-date information about the status of serviceability, safety and durability leading to a minimization of service disruptions.
2. Performing continuous or timely non-destructive testing leading to the optimization of resources for repair, rehabilitation, or replacement.

To attain both benefits, many Innovation & Information technologies are used to collect, store and digest the information, process it and take the appropriate action.

Here is a good example: according to the statistics gathered in the US and Canada, the number of structurally deficient bridges/buildings is very large. One might argue that there is no need for more complex or costly sensing systems since the problem resides in a shortage of repair funding; this type of thinking is short-sighted. The installation of sensing systems allows early detection of problems such as corrosion, concrete cracking, fatigue, overstress, disbanding of reinforcements, etc. Then, removal of the factors causing the problems can prevent the need for major rehabilitation or replacement in the future. If moreover as stated before, actuators are added to the structure to react, adapt and adjust its response to the applied solicitations, the system is then called a smart system.

SHM APPLICATIONS

The potential market for the application of SHM can be quite large. As mentioned previously, candidates include bridges, dams, buildings, skyscrapers, etc. although sensing systems have also been used in applications such as buried structures and pipelines among others. Monitoring systems can provide information regarding damage and deterioration of structures, but it can also be used to monitor serviceability limits during construction and/or provide critical information throughout the service life of a structure.

Fatigue cracks and corrosion are a constant concern for both new and aging metallic structures. Concrete must deal with similar concerns with its steel reinforcement, in addition to inadequate or incomplete concrete curing and cracking and bond failure of reinforcement (internal rebar, external wraps, plates, etc). The evaluation of structural performance during and damage detection immediately after major hazardous events such as earthquakes and floods can be an invaluable resource in understanding future structural behaviour.

SHM COMPONENTS

Until now, the use of SHM systems have been predominately in bridges [2], but monitoring systems have also been shown to provide vital information for a multitude of civil engineering applications, including for buildings.

In order to use sensors to detect damage, a high degree of knowledge of the type of damage that is to be expected and where this damage may occur is required. This can be difficult in buildings. If using SHM to monitor or evaluate an already damaged structure, then the location of the damage is easily determined. In new structures, it can be very difficult to predict what part of a structure might be most at risk, since all components should be designed with a particular factor of safety.

Each structural system to be monitored requires specialized and careful preparation. On the other hand, commonalities do exist amongst all monitoring systems. These include the need to fully understand or accurately predict the behaviour of the structural element(s) of concern, an idea of what parameters will be monitored and how, as well as how data will be transmitted, managed, and dealt with. Many common factors must be considered before attempting to implement any SHM system. They are:

Type of Structure

A full and thorough understanding of the structural component under consideration must be obtained before any sensing system can be chosen. Any new construction should already contain a complete and accurate structural analysis of all system members. However, the installation of monitoring systems on old and potentially damaged structures demands updated analyses which estimate strength reductions based on the extent of damage incurred.

SHM systems will most commonly be applied to the structural components of buildings. Nearly all large buildings have structural systems constructed of steel and concrete, although smaller buildings commonly use masonry and wood as structural components as well. Each of these materials has differing physical characteristics, and mechanical properties. The type of material will significantly influence the types of sensing methods possible as well as sensor bonding procedures.

Type of Sensors

It must be noted that no sensor can directly measure damage itself. A sensor can only measure an effect that may be caused by damage. Commonly monitored parameters include: displacement, strain, temperature as well as acceleration.

Various forms of sensing systems to monitor the parameters just mentioned have been investigated and tested worldwide. These methods include fibre optic sensing, vibration and wave-based techniques, electromagnetic field as well as satellite monitoring. Research into countless other methods continues to emerge, expanding the sensing possibilities of civil infrastructure.

Regardless of the type of sensor required, sensor manufacturers will require an estimation of the expected change in the monitored parameter. For example, if measuring strain, the range of deformation will determine the type of sensors available.

The Viaduct de Millau, France is a state of the art example of the use of fibre optics for SHM. The pylons, masts, decks and cables are all equipped with a multitude type of sensors (anemometers, accelerometers, extensometers, inclinometers, vibrometers, etc) to detect movement, temperature changes, vibrations, etc. Another example is the Confederation bridge in PEI with its many sensors to assess ice solicitations.

Sensor Placement

In order to maximize the usefulness of SHM sensors, one must ensure they are concentrated on particular weak points or specific failure paths in the structure. Only through the appropriate placement of sensors in the structure can the proper benefits of a monitoring system be realized.

Methods of sensor placement optimization (SPO) have been tested by various researchers. These methods however are designed to analyze a specific component to determine the mostly likely areas of concern. Before SPO can be performed however, it is necessary to determine which structural components must be monitored. Buildings are often composed of load-sharing systems, in which there may not necessarily be one exact component which can give a global view of the structural health. Careful examination is then required to establish meaningful sensor placement, and feasibility of an SHM system for the particular application.

<u>Strain Gauges:</u> It is well-known and accepted worldwide and used in a great variety of applications. The strain gauge technology provides high accuracy at low price levels.

Over the past several years, research in the field of fibre optics has revealed a new type of sensing medium—fibre optic sensors.

<u>Fibre Optic Sensors (FOS)</u>: Due to the recent boom in the telecommunication industry, the cost of fibre optics components has dropped dramatically. This has enabled engineers to expand the possible applications for fibre optic strain measuring devices. Some of the most promising techniques are based on the use of fibre-optics.

The general principle of FOS is that light from a laser source sent through an optical fibre experiences subtle changes of its parameters either in the fibre or in one or several fibre Bragg gratings, and then reaches a detector arrangement which measures these changes. A calibrated computer program, connected directly or remotely, can then read the changes and output the strain in one or more places along the fibre.

When promoting the use of FOS, both manufacturers and users list the same benefits almost universally: Absolute measurement; Immunity to electromagnetic interference (EMI); Excellent resolution and range; Passive operation; Water and corrosion resistant; Compact and simple; and finally Multiplexed in parallel or in series (can examine multiple sensors in a single fibre line with a single optical source).

<u>Vibration and wave-propagation based sensing</u>: Vibrational sensors can be installed on structural elements in order to monitor their dynamic response to either ambient, or forced vibration sources of structural excitation. Ambient excitation sources include wind, seismic activity, traffic, waves or tidal fluctuations and even ground vibration generated by nearby industries. These ambient sources can be valuable when frequencies are appropriate, and the variability in amplitude and duration are minimal. When ambient vibrations aren't suitable, vibrations can be created by shaking machines and impact hammers. Monitoring can

include the global structural behaviour, or it can be concentrated on specific structural elements.

Wave-based sensing has also seen use in SHM. Tap tests can give a general idea of the presence of damage by comparing acoustic signals obtained by tapping various areas of a structural element with signals of a known undamaged area. One of the most commonly used inspection techniques for steel structures uses ultrasonic waves. This method involves inducing a sound beam in the material. Through interpretation of the reflected waves, it is possible to detect cracks and determine the location and size of defects.

Data Acquisition Systems

Data acquisition typically involves acquisition of signals and waveforms, then processing the signals to obtain desired information. Sensor manufacturers generally sell sensing components with fully equipped data acquisition systems having software for complex signal analysis, modal analysis and pattern recognition.

Data Transfer and Storage Mechanisms: Data can be transferred by cables or wirelessly to a central server where it can be stored for analysis. It has been shown that a single server is capable of collecting sensor information from not only multiple sensors, but also from multiple buildings. Transmitted or uploaded data can be stored in XML files in designated directories, and accessed by one or more users for data analysis.

Data Interpretation and Diagnosis: Damage analysis is often done by statistical models or damage detection algorithms. They can be composed of pattern recognition methods such as expert systems, neural networks, probability density estimators, or negative selection algorithms, or can be made of linear algebraic finite element methods.

Before any damage detection can be made, a set of "baseline" measurements must first be taken to provide a normal condition state with which to make any future comparisons.

The damage state of a system can be described by answering the following four questions: is there damage in the system? Where is the damage in the system? What kind of damage is present? How severe is the damage?

Answers to these questions in order represent increasing knowledge of the damage state. If the measured system response data exceeds some pre-determined threshold, one can then conclude that damage has occurred. In making this conclusion, one must ensure that the change in data is not caused by operational or environmental variability. The more sensitive a measurement is to damage, the more sensitive it is to changing operational and environmental conditions as well. These environmental factors include temperature cycling; wind, snow and earthquake loadings and frost heave.

The ultimate goal of SHM systems is to mitigate future problems or catastrophes through early detection. Any damage analysis should therefore conclude with a prediction of the remaining service life, and recommended techniques for rehabilitation.

CHANGES REQUIRED FOR WIDESPREAD IMPLEMENTATION

The construction sector is generally very conservative. Owners and operators are wary of the responsibility of implementing SHM systems of their own due to the lack of code procedures. These owners need to ensure that the expenses will provide them with some sort of benefit, especially because small reductions in structural risk are difficult to quantify in value. Financial incentives, or code certification for improved structural monitoring could help propel SHM well beyond the realm of research. There is no doubt that cost is a significant drawback to most SHM applications. Instrumentation providers need to continue to reduce the cost of their sensor interrogation systems [3].

Finally, the transfer of technology from the research laboratory to practice is done on an on-going basis by communicating and cooperating with industry and infrastructure owners in the formulation and undertaking of field demonstration research projects. Such demonstration projects are essential to bring about a sharing of knowledge and future changes in code standards.

RECOMMENDATIONS

A full investigation into each possible sensing system and their associated costs would provide a more robust report with which to compare methods and to evaluate the pros and cons of each system. Distributed fibre optic sensing systems may have been overly complex and costly for small buildings, but there still may be other available sensing apparatus that could properly fit this type of budget.

An improved method of collaboration between the manufacturers of SHM technologies, researchers and industry would greatly increase the possibilities for future use of the sensors. These sensing systems require a proper understanding of their capabilities and limitations, and should be installed with care and precision to ensure meaningful results. There currently seems to exist a large knowledge gap between the designers/manufacturers and the structure owners/builders on what various sensing systems are capable of. Manufacturers tend to push their own products, as opposed to helping facilitate the proper solution to one's problem. Owners and builders often have no background on how sensing technologies work, and have no idea where to begin. Therefore, there needs to be some sort of information gateway for owners and builders—not researchers—to learn about the costs and benefits of structural health monitoring and whether or not a viable solution could be available for their next project.

RMC CENTRE FOR SMART MATERIALS AND STRUCTURES (CSMS)

Recent scientific advances in new emerging materials and information technologies have led to the development of smart technologies which include smart materials, structures and systems. These technologies possess the capability to respond in a controlled manner to various ambient stimuli by sensing and actuation. This is a very fast-evolving field of research.

Since its inception in 2005, CSMS (www.smartmaterials.ca) has been working with national & international R & D teams on a variety of smart materials, structures and systems. CSMS is very active in the design and production of sensors and actuators as well as active, adaptive and smart structures using emerging materials in order to produce systems for practical applications. The primary goal is delivering innovative research in smart materials, smart structures and smart

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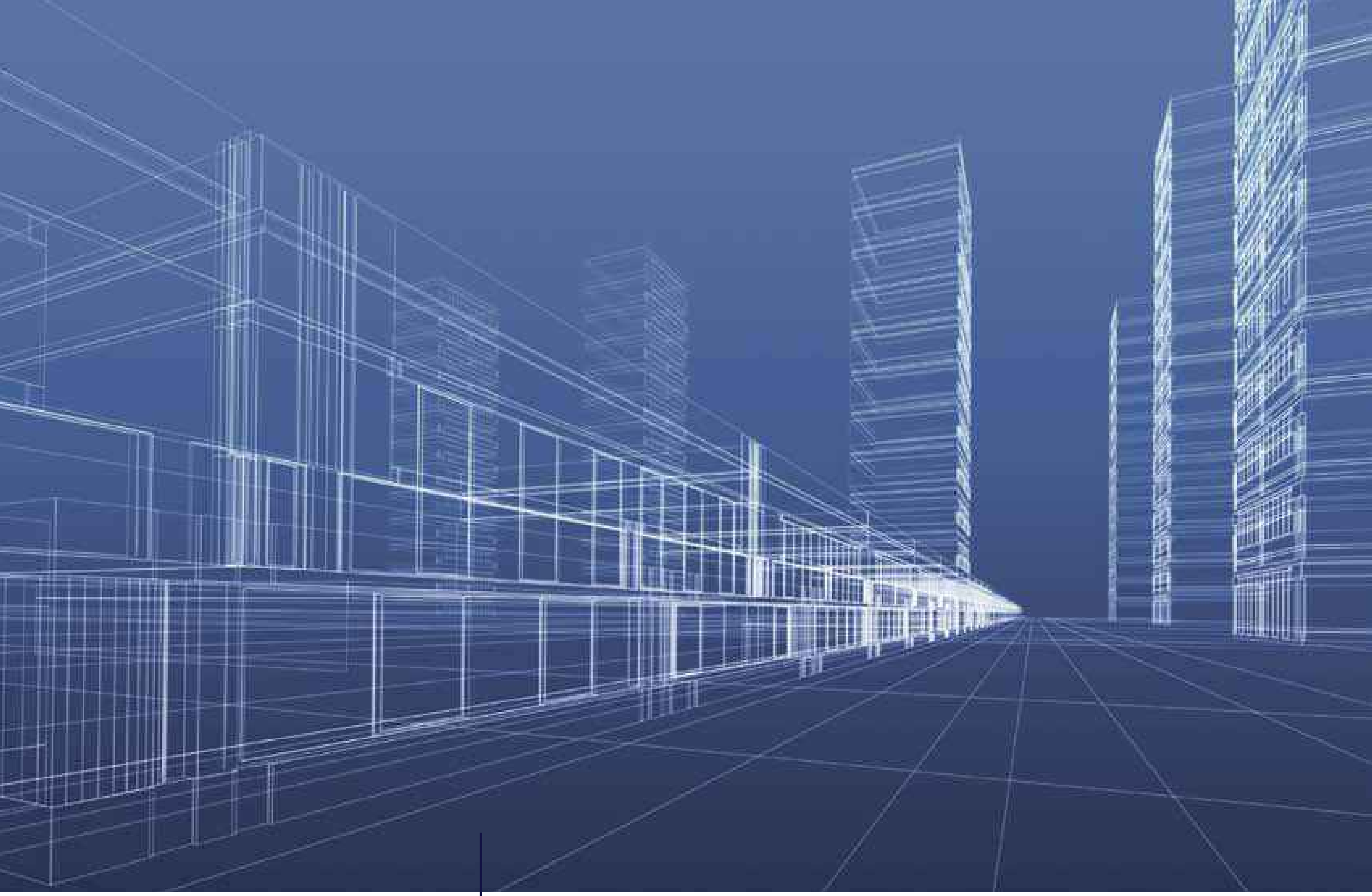

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Blast Loads on Buildings: Accuracy and Reliability

INTRODUCTION

The assessment of a building vulnerability to a given blast scenario is a relatively new field on the civilian side of structural engineering as attested to by the absence of specific consideration of this type of loading in national building codes and in structural design standards. Also, the majority of structural designers lack the kind of experience with blast design as they have with other types of loads, such as wind and seismic; therefore, they cannot draw on their past experience, or the guidance that is normally provided by codes and standards, to assess or design buildings against blast loads. Consequently, generally they need to apply basic theories of structural dynamics and fundamental constitutive laws of materials under fast strain rates in order to arrive at a reasonable solution. The two key elements of structural analysis are determination of the load acting on the structure and the application of a suitable method of analysis to find the internal forces that equilibrate the external loads. In this article, some issues related to blast load on buildings due to an external explosion are discussed and some general recommendations are made.

EXPLOSIVE DETONATION AND RESULTING BLAST PRESSURE

When compared to other types of dynamic loads, such as wind and seismic loads, blast loads from high condensed explosives possess some peculiar features (FEMA, 2003), such as large magnitude, high rate of decay with distance from the explosion source, extremely short duration, unusual propagation direction/pattern, interaction with the target surfaces (reflection, diffraction, clearing effect, wrap around effect) and high uncertainty. To shed some light on these issues, it is useful to consider the detonation of an explosive charge and the phenomena associated with it.

A detonation is a self-sustained reaction which produces gases at high temperature and pressure (up to 4000°C and 30 GPa). The gases expand violently and compress the surrounding medium to create a highly compressed region, known as the reaction zone. The interface between the gases and the surrounding medium is called shock wavefront, which initially propagates through the charge, consuming the reacting compounds in the process. Subsequently, the expansion continues through the medium surrounding the charge, forcing it out of its previously occupied space and generating a thin, highly compressed layer known as the blast wave, which propagates at supersonic velocity (Smith and Hetherington, 1994).

In the case of a spherical charge in free air centrally initiated, the blast wave may be pictured as a spherical air bubble expanding radially outward from the charge centre. Behind the shock wave, where a vacuum is created, air rushes in, creating a powerful drag pressure commonly known as blast wind, which is often responsible for the flying debris caused by blast.

As the expansion continues, the pressure at the wavefront, known as side-on overpressure, or incident pressure, decreases rapidly in space (approximately with the cube of the distance from the charge) due to the bubble volume increase and the heat exchange with the surrounding medium, and it decreases exponentially with time. For conventional explosives of up to several thousand kilograms, the intense blast wave pressure typically lasts less than a second and generally a few milliseconds (FEMA 2003, Baker et al., 1983). After the pressure at the wavefront drops to the atmospheric value, usually the shock wave goes into a phase of overexpansion. During this phase, also known as the negative or suction phase, the pressure at the wavefront drops below the atmospheric value, causing a flow reversal. The end of the suction phase indicates that a new equilibrium has been reached and the blast wave has vanished. In an external explosion, a portion of the energy is also imparted to the ground, creating a crater and generating a ground shock wave analogous to a high–intensity, short–duration earthquake. The typical time-variation of the pressure at the shock wavefront is depicted in Figure 1, which was recorded in recent field tests performed by the writers.

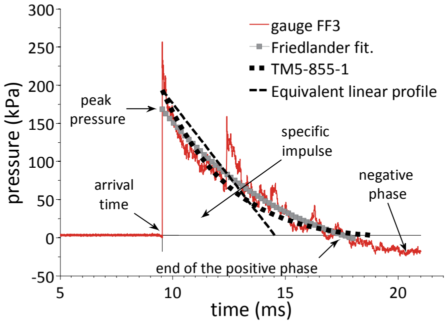

FIGURE 1: Incident pressure produced by a 90 kg charge of ANFO explosive at a standoff distance of 10 m, corresponding to a scaled distance Z=2.38 m/kg$^{1/3}$. The red line represents the data recorded by a pressure gauge; the gray line is obtained by fitting the experimental data with the Friedlander equation; the dotted line corresponds to the pressure profile predicted by TM5-855-1; the dashed line is the impulse-equivalent linear pressure profile.

IMPORTANT BLAST LOAD PARAMETERS

Blast wavefront parameters essential to structural design are the peak pressure (kPa), the positive pressure phase duration in milliseconds (ms), the specific impulse delivered by the blast (kPa·ms), which is the area underneath the pressure-time curve from the time of arrival of the shock wave at the target to the end of the positive phase as indicated in Figure 1. Other parameters, such as those pertaining to the negative phase, may be also important in some design situations.

From empirical evidence, all wavefront parameters may be expressed, at sea level, as function of the so-called scaled distance $Z=SD/W^{1/3}$, defined as the ratio of the standoff distance, SD, to the cubic root of the mass of the explosive charge, W, where SD is expressed in meters and denotes the distance between the charge centre and the point in space where the wavefront parameters are calculated; W is expressed in kg of TNT equivalent. Accordingly, the mass of any explosive material need be converted to an equivalent mass of TNT through multiplication by factors obtained from principles of energy, impulse, or peak pressure equivalency (Baker et al., 1983).

In order to establish the blast pressure acting on the external surface of a potential target, however, the mere knowledge of the pressure variation at the shock wavefront is not sufficient. When the building is stricken, a complex series of events take place, such as reflection, diffraction, and rarefaction of the blast waves and formation of vortices, and all these phenomena contribute to the magnitude of the final loading. Depending on the type of scenario, some of them may be more relevant than others. For instance, if very simple geometries are involved, such as box-shaped buildings, vortices may be disregarded as a minor perturbation of the average pressure field. Similarly, when the detonation occurs at a distance from a target much greater than the dimensions of the target, e.g. one order of magnitude larger than the longest dimension of the building, then the shock waves may be considered planar, i.e. a wave which impacts each building surface with a fixed angle of incidence and uniform pressure. However, the variation of angle of incidence over the reflecting surface usually has important effect on the actual pressure distribution, as does the general geometry of the target building, and more generally, the urban landscape or topography surrounding ground zero (Gebbeken and Doge, 2010). Note that planes parallel to the direction of travel of the blast wave are subjected to incident pressure, which is significantly lower than the reflecting pressure acting on planes that are not parallel to the wave travel direction. Hence, for an explosion in front of a building, the face of the building will experience much greater pressure and impulse than its rear and side walls and roof.

Additional pressure may be exerted on buildings or other objects by the blast wind which is proportional to the product of the square of the wind velocity, the exposed surface area and the drag coefficient. If this force exceeds the resistance of the building to motion in the direction of the blast wind, it may move or displace the building, albeit large reinforced concrete and steel buildings would be difficult to displace due their large size and well anchored foundation. For objects that are not anchored into the ground, e.g. vehicles, the resistance to motion will be function of their mass and the coefficient of friction at the contact points between the ground and the object. Blast winds, however, arrive later than the shock wavefront; therefore, the pressures from these two sources do not act at their maximum intensities concurrently.

To illustrate some of these features of blast load, consider the simple case of a vehicle parked along the curb directly across the front of a four storey building and loaded with 225 kg (~500 lb) of uncased TNT explosive. Assume the horizontal distance between the charge and the building façade to be 10 m, the façade to be approximately 12 m high and 20 m wide, and the charge to be located on the ground. For this scenario, the smallest scaled distance (for the point on the façade closest to the explosive) would be Z=1.64 m/kg$^{1/3}$ and its associated peak incident pressure and specific impulse could be determined to be approximately 450 kPa and 1000 kPa·ms, respectively. It is safe to say that this level of pressure is a couple of orders of magnitude larger than the typical load that a normal residential or office building is designed for. For example, typical live and wind loads for which buildings are designed are less than 5 kPa.

Despite the fact that the magnitude of the blast pressure is normally extremely high compared to other types of loads acting on buildings, due to the dynamic nature of the blast load and its relatively short duration, some components can resist these loads without experiencing severe damage. As far as the overall response of the building is concerned, since the wavefront pressure decreases with the cube of distance from the charge centre, the resulting pressure distribution on the façade is highly non-uniform, and if damage were to be caused, it is likely to be severe damage in those parts of the building located closest to ground zero and directly facing it. Localized damage is more likely to happen as the standoff distance is reduced, and the type and extent of damage would depend on the strength of individual elements in the proximity of ground zero. It is normally the failure of key supporting elements that leads to disproportionate or progressive failure of the building, but if the building is designed against progress collapse, total building failure may be averted.

The positive phase duration associated with the previously calculated scaled distance of 1.64 m/kg$^{1/3}$ is of the order of a few milliseconds (12–13 ms), which is typical for this kind of blast scenario. In this respect, blast events are very different from wind and seismic events, which are often measured in seconds or minutes, and this holds the key to the resistance of building to loads of such large magnitude. The mass of the building also has a strong mitigating effect on its structural response. The larger the mass, the larger the natural period of vibration of the building and the smaller the ratio of the positive phase duration of the blast pressure to the fundamental period of the structure. Response spectra, (Biggs, 1964) indicate that a reduction of this ratio induces a reduction in the structural response as well, with obvious beneficial effects on the post-blast serviceability of the building. Here we can see that the response of buildings to blast loads differs from their response to seismic loads because under blast loads larger mass reduces building vulnerability to damage while under seismic loads it increases it.

METHODS OF DETERMINING BLAST LOAD PARAMETERS

Rigorous computation of blast wavefront parameters and the resulting blast loads on structures are rather complex tasks. The problem can be analyzed by considering three different regions; namely, inside the explosive charge, in the medium in the immediate vicinity of the charge, and finally in the region located at some distance from the charge. There are essentially two methods available for determining the blast load parameters, theoretical/numerical and empirical methods.

Theoretical/Numerical Methods

Regardless of the region of space being considered, the physics of the blast problem may be represented by a set of partial differential equations derived from first principles, namely, conservation of mass (continuity equation), conservation of momentum (Euler's equation), conservation of energy, thermodynamic state of the system (equation of state), definition of internal energy of the system (equation of internal energy), and modeling of the detonation and expansion process which depends on the type of explosive charge in use (Chapman-Jouguet, Jones-Wilkins-Lee, etc.). Unknown wavefront variables are pressure, density, particle velocity, temperature, internal energy, and entropy. Given the proper boundary/initial conditions for pressure, particle velocity, and flow density, the system can be solved by means of the so-called hydrocodes or computational fluid dynamics (CFD).

Hydrocodes and CFD can only be practically used if these methods are implemented in computer programs. The computer program, or hydrocode, analyzes the effect of external and internal forces on a collection of elements or cells used to represent the actual volume of interest affected by the blast. It assumes that these forces remain constant over a small increment of time and uses them to adjust the geometry of the cells in order to satisfy the above conservation laws and other relevant conditions. Iterations are made to achieve satisfaction of the conditions, and the process is moved in time for a new set of forces.

A shock wave is associated with essentially an instantaneous jump in pressure, velocity, density and internal energy. Although the shock is blunted somewhat by mechanisms such as viscosity and material damage, nevertheless, rapid changes that occur over shorter distances than the smallest possible cell size complicate the numerical solution process and its convergence, hence to achieve proper convergence, the shock wave problem needs special treatment for obtaining realistic results. Knowing this, the results of hydrocodes must be carefully examined and their accuracy and validity must not be taken for granted.

Since this is a very laborious and time consuming method, which requires a high level of expertise in fluid mechanics, finite element/finite difference/finite volume modeling, and structural mechanics, more simplified methods and software have been developed over the years, which of course lack the generality and accuracy of CFD and hydrocodes, but they are simpler to understand and apply. These methods are empirical and are based on data collected from arena tests involving high density explosives as described in more detail below.

Empirical Method

This method essentially relies on a large database of experimental data, and the richness and comprehensiveness of the data define the accuracy of its results. The

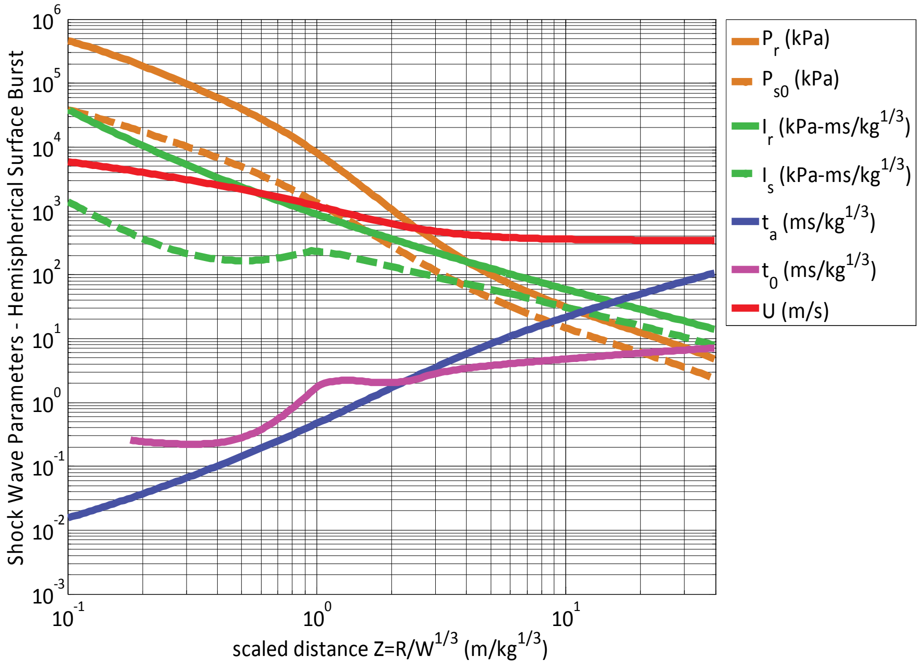

FIGURE 2: Shock wave parameters for hemispherical TNT surface burst at sea level, adapted from Figures 3–7 of the Technical Manual TM5-855-1 (USACE 1986). P_r denotes the peak reflected pressure, P_{s0} is the peak incident pressure, I_r is the reflected specific impulse, I_s is the incident specific impulse, t_a is the time of arrival, t_0 is the positive phase duration, and U is the shock wavefront velocity. The parameters related to the reflected shockwave were obtained for a zero angle of incidence.

method may employ simplified or detailed approach, using either charts, Figure 2, or mathematical functions obtained by best fit of the experimental data, assuming all wavefront parameters to be function of scaled distance.

The simplified approach is outlined in TM5-1300 (US Department of the Army, 1990), superseded by UFC 3-340-02 (US Department of Defence, 2008). Basically, the target structure is divided into a number of parts, and for each part peak pressure, impulse, and positive phase duration are evaluated using charts similar to Figure 2, based on the assumption that pressure-time history decays exponentially. In this approach it is further assumed that all points on a given part are subjected to the same pressure and impulse at a specified time. This hypothesis, although reasonable for a large standoff distance to building dimensions ratio, leads to inaccurate results in case of medium and close range explosions.

As alternative to graphs and charts, the blast load software CONWEP (Hyde, 1990) may be used. In this software high degree polynomials are fitted to the empirical data (Kingery and Bulmash, 1984). The pressure-time history is represented by an exponential function, known as the modified Friedlander equation (Baker et al., 1983). As far as above-ground structures are concerned, the program provides incident and normally reflected wavefront parameters for a given charge mass and standoff distance, as well as peak reflected pressure, reflected impulse, positive phase duration, and decay coefficient. The software also accounts for so-called clearing effects. Since the target surface is assumed to be rigid, wave-structure interaction is neglected, leading to conservative pressure values in case of simple geometries. The two CONWEP sub-routines most relevant to this discussion are dubbed "Aboveground detonation" and "Loads on structures". Beside the charge mass, the "Aboveground detonation" subroutine requires only the standoff distance to be entered, intended as the distance from the centre of the charge to the point of interest on the reflecting surface. The angle of incidence is assumed to be 0° and the output is given in a numeric form for all wavefront parameters. As for the "Loads on structures" subroutine, two different scenarios are implemented, depending on the target orientation. In the horizontal configuration, a rectangular surface is assumed to be located directly beneath a spherical charge suspended in the air at a certain altitude while in the vertical configuration, a vertical rectangular surface is assumed to be facing a hemispherical charge sitting on the ground. These configurations are intended to represent free-air burst and surface burst, respectively. Both scenarios require, as input data, the coordinates of the two corners (bottom-left and top-right) of the reflecting surface, as well as the coordinates of the two corners of the area of interest (target area) within the larger surface. The origin of the frame of reference coincides with the centre of the charge. The target area is divided into a 64 × 64 grid and the output is given in a numerical form, as a matrix of wavefront parameters calculated at any point of the grid, or in graphical form, i.e. contour lines.

Another blast load software called AT-BLAST (ARA, 2004) estimates blast loads due to surface-burst. The program allows the user to input minimum and maximum standoff distance, explosive type and charge mass, and angle of incidence. From this information, it calculates shock front velocity, time of arrival, peak reflected pressure, reflected impulse, and loading duration. The pressure profile is assumed to be decay linearly. With the exception of the load duration, all other output quantities from this software are in agreement with those from CONWEP.

The detailed approach takes advantage of experimental data and empirical formulas in a more refined fashion. It attempts to capture the most relevant physical processes and model them in a simplified fashion. This approach may be used to obtain a more realistic and accurate distribution of blast pressure, impulse or other relevant parameter variation over the surfaces of a building. The variation would be caused by appreciable changes in standoff distance and angle of incidence from one section to another section on a given surface of the building. Figure 3 shows the results of such a detailed approach presented in the form of contour plots, depicting the variation of the blast wavefront parameters over the front façade of the hypothetical building hit by a 225 kg car bomb as described earlier. This analysis was carried out by dividing the façade into a 64 × 64 grid and evaluating, at each node, all the wavefront parameters, accounting for the variation of the standoff distance, angle of incidence, and distance from the edges of the facade.

Between the two methods, i.e. CFD/hydrocodes versus empirical, use of the

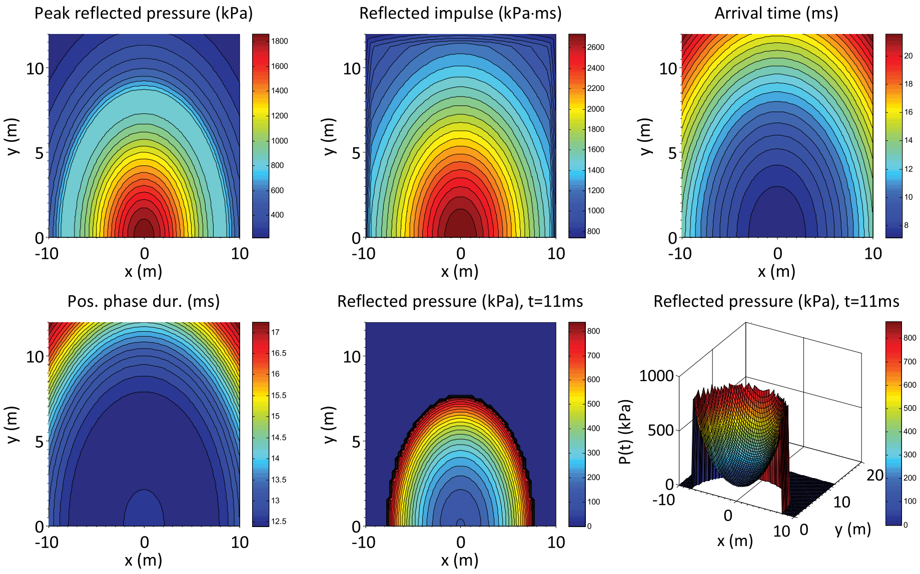

FIGURE 3: Detailed calculation of the shock wavefront parameters and the pressure distribution over the front façade of a four storey building facing a 225 kg TNT charge detonated on the ground at 10 m from the closest point on the reflecting surface by empirical method.

former can only be justified if one were designing or evaluating a structure against a very well defined precise threat scenario. Instances when this method is likely to be required, unless ad-hoc semi-empirical solutions are available, include close-in explosions, complex geometries, and complex urban environment and topography. Close-in explosions refer to detonations of a charge at a scaled distance below approximately 0.4 m/kg$^{1/3}$ (1 ft/lb$^{1/3}$) and involve a wide range of phenomena which cannot be accounted for by empirical or semi-empirical means. The complexity of the geometry of the building and its surrounding landscape and architecture similarly complicate the problem due to the interaction of the air flow with the reflecting surfaces surrounding ground zero, including multiple reflections, diffraction and rarefaction of shock waves, formation of vortices, etc. The presence of re-entrant corners, parapets, balconies, false works, and other such features generally renders inadequate available empirical methods.

Another important consideration from a structural engineer's point of view is lack of expertise in the area of computational fluid dynamics and shock wave propagation, and the numerical procedures pertinent to the implementation of these theories in computer codes. The method is also very time-consuming and expensive to apply, particularly to full size structures and the computing requirements can easily exceed the capabilities of most ordinary desktop and laptop computers used in structural engineering design offices. Similarly, it can take from many hours to many days to analyze only one scenario. It is safe to state that this method is generally beyond the means and the usual competencies of the vast majority of structural engineering firms. Consequently, practically, the real choice is between the simplified and detailed empirical approaches.

To choose the appropriate empirical approach, the first issue to be considered is what kind of pressure differential is expected between the different parts of the same reflecting surface. An important clue is offered by the type of decay the blast pressure undergoes as the distance from the centre of the charge increases. From empirical data, as well as numerical investigations of the differential equations describing the propagation of a shock wave in air, it emerges that the peak pressure is approximately inversely proportional to the cube of the standoff distance. This simple fact highlights the relative value of the standoff distances to the size of the building surfaces struck by the shock waves. From basic geometrical considerations, it follows that for ratios of these values larger than for instance ten, the standoff distance associated with the different points on the building envelope does not vary significantly, and the blast waves may be safely calculated assuming using the simplified approach. Otherwise, the detailed method should be used and generally the reflecting surface should be divided into smaller and smaller sections, until the difference between the calculated impulse values of two adjacent sections is not greater than 10% of the larger of the two impulse values. Computer programs such as CONWEP use a somewhat similar procedure.

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As summer turns to fall and back-to-school season begins it's difficult to not get caught up with a sense of renewal and a desire for a fresh start.

Many of us are starting our first job out of university or looking to the future and setting goals for career development. We are all anxious to improve our technical skills and build on the knowledge gained in university or during summer jobs or internships, yet we are told that one of our priorities should be to improve our 'soft skills'.

What are these soft skills exactly and how important are they? Essentially, soft skills are all the other areas of knowledge, besides technical, that you need to be successful at work and in life. They include items such as communication, time management, organizational skills, leadership, teamwork, and adaptability. Employers often consider these skills "work readiness" and a candidate or employee with similar technical skills to others but with highly developed soft skills will often be the one considered for the job or the promotion.

How can you improve these skills and ensure that you are the candidate that gets ahead? One starting point is to evaluate your current strengths and weaknesses. A simple way to do this is to take a minute to complete this short quiz (www.bettersoftskills.com/quiz/index.php) that identifies your strengths and points out areas where you may need some work.

A great resource to look to for improving in areas where you may need a bit of work is the CSCE. As your local section is gearing up for another season of informative lunch or dinner presentations, you may find that some of the topics are geared towards soft skills improvement or that they are offering additional soft skills sessions and workshops. Or better yet, get involved and put your soft skills to work. Volunteer to help out your local CSCE section or join a committee at the National level. Being part of a CSCE committee or section, attending executive meetings and helping to organize events are all great opportunities to improve your soft skills outside of work pressures in a more relaxed atmosphere.

When you are considering putting your soft skills into practice don't forget about our Young Professionals' Committee. There is a lot of opportunity to get involved. Keep in touch, even if just to pass along suggestions for future events. I look forward to hearing from you. ■

Alors que l'été s'achève et que s'amorce la rentrée, on ne peut s'empêcher d'éprouver un besoin de renouveau et un désir de prendre un nouveau départ.

Certains d'entre nous débutent dans un premier emploi à la sortie de l'université ou planifient leur avenir en se fixant des objectifs de carrière. Nous voulons tous améliorer nos compétences en construisant sur ce que nous avons appris à l'université, pendant nos emplois d'été ou pendant nos stages. Pourtant, on nous répète que l'une de nos priorités devrait être d'améliorer nos compétences non-techniques.

Mais quelles sont ces compétences non-techniques et quelle est leur importance? En fait, ce sont toutes les formes de savoir autres que le savoir technique, tout ce dont vous avez besoin pour réussir, au travail comme dans la vie. Cela comporte notamment les communications, la gestion du temps, les techniques d'organisation, le leadership, le travail en équipe et la faculté d'adaptation. L'employeur considère souvent ces éléments comme des critères d'emploi, et, à compétences techniques égales, le candidat ou l'employé qui présente des compétences non-techniques supérieures sera souvent choisi pour combler un poste ou obtenir une promotion.

Comment améliorer ces compétences et comment devenir le candidat qui sera retenu? Commençons par évaluer nos forces et nos faiblesses. La façon la plus simple de procéder est de remplir un bref questionnaire (www.bettersoftskills.com/quiz/index.php) qui permet d'identifier vos forces et de préciser les domaines exigeant un peu de travail additionnel.

La SCGC est l'une des ressources à votre disposition pour votre perfectionnement, dans les domaines où un effort s'impose. À l'heure où votre section locale organise une nouvelle saison de déjeuners-causeries, vous constaterez que certains sujets abordés ont trait au perfectionnement ou que la section offre des ateliers sur les compétences générales. Vous pouvez aussi participer aux activités et mettre vos compétences générales à l'épreuve. Faites du bénévolat pour votre section locale ou devenez membre d'un comité au niveau national. Faire partie d'un comité ou d'un chapitre de la SCGC, participer aux réunions de direction et aider à l'organisation d'activités, voilà autant de façons d'améliorer vos compétences générales hors des contraintes du milieu de travail, dans une ambiance plus détendue.

Et si vous songez à mettre vos compétences générales é l'épreuve, songez à notre Comité des jeunes professionnels. Les occasions de participer ne manquent pas. Gardez le contact, ne serait-ce que pour faire des suggestions pour les activités à venir. J'attends de vos nouvelles! ■

SPOTLIGHT ON MEMBERS / MEMBRES EN VEDETTE

Mohamed Attalla PhD., P.Eng., FCSCE receives Engineering Medal for Management

Dr. Mohamed Attalla has been awarded the 2011 Ontario Professional Engineers Award Medal for Management. Dr. Attalla is the Senior Construction Administrator at the Toronto District School Board (TDSB). He leads a team of 500 professionals to service the needs of the more than 600 TDSB schools and other buildings. Dr. Attalla's expert management has allowed facilities to be constructed under budget and ahead of schedule, and his school construction projects have been of such interest that property owners and administrators of school boards from across Canada and the United States have come to visit them. Dr. Attalla possesses a comprehensive experience in the industrial, commercial and institutional sectors, and is internationally recognized for his experience in the subjects of management, leadership and strategic planning. He is also an adjunct professor at the University of Waterloo and Ryerson University.

COMING EVENTS / CALENDRIER DES ACTIVITÉS

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May 22–25, 2012
http://www.acmbs2012.ca

2012 CSCE Annual General Meeting and Conference
Edmonton, AB
June 6–9, 2012
http://www.csce2012.ca

15th International Specialty Conference on Cold Regions Engineering
Quebec City
August 19–22, 2012
http://www.csce.ca/2012/iccre

International Venues

International Conference on Drinking Water, Safety, Security and Sustainability
October 9–11, 2011
Hangzhou, China
http://drinkingwater.zju.edu.ca

Seismic Protection of Cultural Heritage
October 31–November 1, 2011
Ankara, Turkey
http://e-imo.imo.org.tr/portal/web/Organizasyon/Default.aspx?id=4

Coastal Management 2011: Innovative Coastal Zone Management: Sustainable Engineering for a Dynamic Coast
November 15–16, 2011
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continued from page 21

systems which have real impact and provide value to our partners. ■

NOTE: The Canadian Smart Materials and Structures (Cansmart) Group organises a yearly international workshop on Smart Materials and Structures. For more information, please check www.cansmart.com.

*This article incorporates the reporting of research conducted at the RMC Centre for Smart Materials and Structures (www.smartmaterials.ca) under the direction of the author by several colleagues & students.

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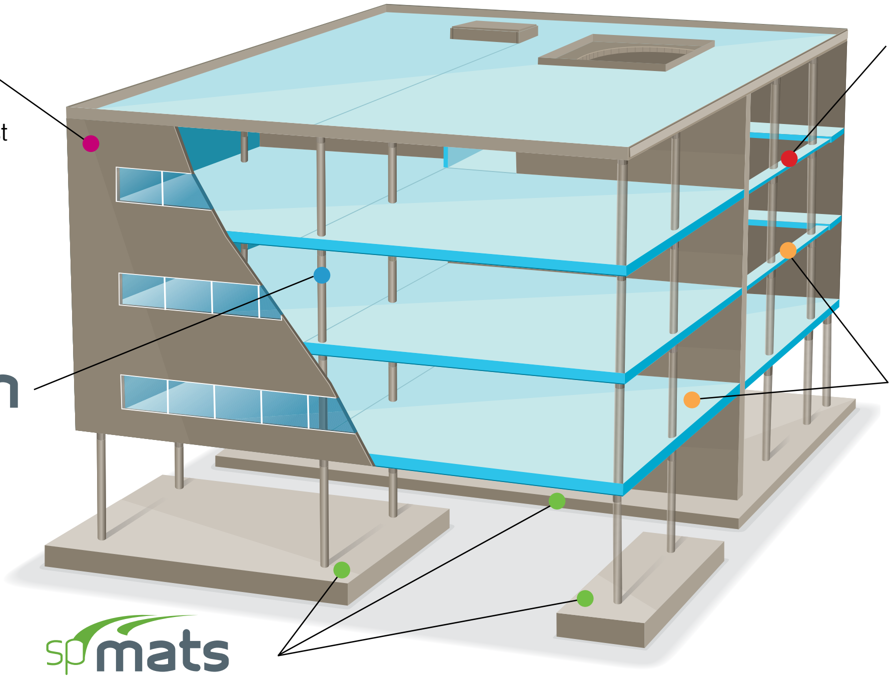

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