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Accelerated Bridge Construction
La construction de pont en accéléré

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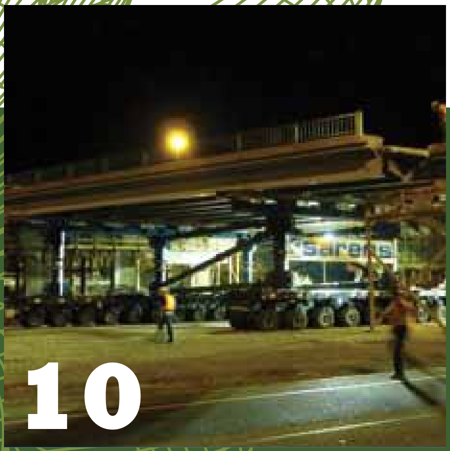

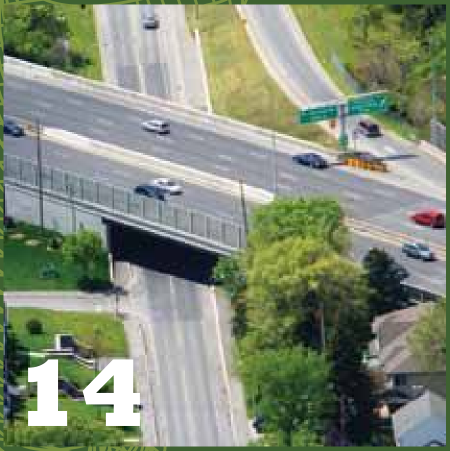

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FROM THE EDITORS / MOT DES RÉDACTEURS

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Bridges built prior to the 1970's did not use air-entrained concrete and coated reinforcing steel bars to protect from the effects of freeze-thaw cycles and the application of winter de-icing salt. This leads to corrosion-induced degradation in bridge elements. Accordingly, exposed bridge elements are all likely candidates for expensive replacement on the majority of these older bridges. It is estimated that over 40% of all bridges in Canada are older than 40 years and are in need of rehabilitation or replacement. The backlog of maintenance, rehabilitation and replacement of highway bridges is estimated at $10 billion. The current traditional bridge rehabilitation/replacement systems in most situations are very time consuming and costly. The prohibitive costs needed to upgrade bridge structures require the development of innovative technologies to accelerate bridge replacement/repair; and (ii) provide sustainable bridge systems that prolong the service life of the structure.

In November 2007, The Residential and Civil Construction Alliance of Ontario (RCCAO, 2007) released a report on the state of Ontario bridges, entitled "*Ontario's Bridges: Bridging the Gap*." The report warns that the integrity of Ontario's municipal bridge infrastructure and public safety are at risk after years of deferred maintenance, irregular inspections, and lack of government oversight. Recent media coverage on bridge collapses in Laval, Quebec, and Minneapolis, Minnesota, has highlighted the serious consequences of postponing actions to rehabilitate or reconstruct deteriorated bridges and the urgent need to take timely responsible action to safeguard the public from potential infrastructure failure. The study noted that many of Ontario's bridges were built in the 1950s and 1960s, and "it is expected that most bridges will require costly rehabilitation or replacement after 50 years of life." According to a Provincial Auditor's report in 2004, almost one-third of the approximately 2,800 provincial bridges under Ministry of Transportation of Ontario's (MTO) jurisdiction are in need of major rehabilitation or maintenance based on MTO's own figures. However, for the estimated 12,000 municipal bridges in Ontario, the RCCAO report stated that there is a lack of information on their conditions and a capital investment of at least $2 billion would be required over the next five years to rehabilitate this aging infrastructure.

> *"It is expected that most bridges will require costly rehabilitation or replacement after 50 years of life."*

The RCCAO report stated some recommendations to be made to promote the public's safety and the sustainability of Ontario's bridges. One of these recommendations includes promoting bridge engineering designs that improve the life expectancy and reduce maintenance costs of bridges. This can be achieved by using fibre reinforced polymer (FRP) technology. The RCCAO report also recommended seeking accelerated delivery methods to address the mounting infrastructure repair and construction backlog. This can be achieved by utilizing prefabricated bridge elements and connection technology to accelerate bridge replacement, thus reducing lane closure and reducing greenhouse gas emission in transportation.

The use of prefabricated elements and systems in bridge construction has recently been the subject of much attention and interest amongst bridge jurisdictions in USA and Canada as a way of improving bridge construction. Through mass production of the materials, the repeated use of forms, reduction of on-site construction time and labour by concentrating the construction effort in a fabrication facility rather than at the bridge site, significant economic benefits can be achieved. Issues related to work zone safety and traffic disruptions are also a major concern. A full-lane closure is very costly in large busy urban highways

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continued from page 4

because of the significant economic impact on commercial and industrial activities. Prefabricated elements and systems can be quickly assembled, reduce the impact on the environment in the vicinity of the site, and minimize the delays and lane closure time and inconvenience to the traveling public, saving time and spending of tax payers' money. Also, they offer significant social and environmental benefits from the reduction of carbon monoxide emissions.

The featured articles selected for this special issue will provide an excellent overview on the state of the art and state of practice on accelerated bridge replacement and repair. In the first article, Lam and Tharmabala present selected recent implementation of prefabricated bridge elements and connection technologies in Ontario bridges. The second article, by Vachon and Islam, presents field application of bridge rapid replacement in Ontario with self-propelled modular transporters (SPMTs). SPMTs are computer-controlled multi-axle platforms/vehicles that have been used extensively to lift and move heavy equipment and structures for petrochemical, offshore, power, and civil engineering industries. In 2004, an international US scan team saw these amazing machines moving bridges in Europe. Now, this technology is available in Canada to move bridge systems weighing up to several thousand tons with precision to within a fraction of an inch (25 mm). The third article by Sennah, Turnbull, and Young, discusses recent research and field applications on accelerated repair of bridge girders damaged by vehicle impact. Utilizing carbon fibre reinforced polymer (CFRP) sheets in bridge girder repair cuts project schedules from years to sometimes mere weeks or days, resulting in reduced traffic congestion and delays, increased mobility, and improved customer satisfaction. In the fourth article, Sennah presents the summary of the research program conducted by his research team at Ryerson University on accelerated bridge construction and replacement since 2003.

Finally, on behalf on the CIVIL editorial board and the CSCE Structures Division, we would like to thank our contributors who kindly accepted to prepare articles in a very short period of time for this special issue on accelerated bridge construction and repair.

Les ponts construits avant les années soixante-dix n'utilisaient pas de béton aéré et de barres de fer revêtues pour protéger le matériel contre les cycles gel-dégel et l'utilisation de sel de déglaçage en hiver. Cette situation a provoqué la corrosion de certains matériaux. Conséquemment, les matériaux exposés sont tous sujets à faire l'objet de coûteux remplacements dans la majorité des ponts plus âgés. On estime que plus de 40 % des ponts au Canada ont plus de 40 ans et ont besoin d'être restaurés ou remplacés. La valeur des travaux en attente en matière d'entretien, de restauration ou de remplacement de ponts routiers se situe autour de 10 milliards de dollars. Dans la plupart des cas, le système traditionnel de restauration/remplacement des ponts est coûteux et exige beaucoup de temps. Les coûts prohibitifs de réparation des charpentes des ponts exigent la mise au point de technologies novatrices pour accélérer le remplacement/la réparation des ponts et créer des systèmes susceptibles de prolonger la durée de vie des charpentes.

En novembre 2007, la « Residential and Civil Construction Alliance of Ontario (RCCAO, 2007) » a publié un rapport sur l'état des ponts en Ontario intitulé « *Ontario's Bridges: Bridging the Gap* ». Ce rapport prévient que l'intégrité des ponts municipaux et la sécurité du public sont à risque en Ontario, après des années d'entretien différé, d'inspections irrégulières et de manque de surveillance de la part des gouvernements. L'écroulement récent de ponts à Laval, au Québec, et à Minneapolis, au Minnesota, a mis en relief les graves conséquences de la procrastination en matière de restauration ou de reconstruction de ponts trop détériorés ainsi que l'urgence de prendre à temps les dispositions nécessaires pour protéger le public de toute défaillance des infrastructures. L'étude soulignait que nombre de ponts en Ontario avaient été construits dans les années cinquante et soixante et qu'il fallait s'attendre à ce que la plupart des ponts doivent être restaurés ou remplacés à grands frais après une vie utile de 50 ans. Selon un rapport du vérificateur de l'Ontario publié en 2004, presque le tiers des quelque 2,800 ponts provinciaux sous la juridiction du Ministère des Transports de l'Ontario ont besoin d'importants travaux de restauration ou d'entretien, selon les propres chiffres du ministère. Toutefois, dans le cas des quelque 12,000 ponts municipaux de l'Ontario, le rapport de la RCCAO affirme qu'on manque de données sur leur état et que des investissements d'au moins 2 milliards de dollars seront nécessaires au cours des cinq prochaines années pour restaurer ces charpentes vieillissantes.

> *« La plupart des ponts doivent être restaurés ou remplacés à grands frais après une vie utile de 50 ans. »*

Le rapport de la RCCAO formule certaines recommandations pour assurer la sécurité du public et la durabilité des ponts en Ontario. L'une de ces recommandations comporte la promotion de plans de ponts susceptibles d'améliorer la durée de vie des ouvrages et de réduire les frais d'entretien. Cet objectif est atteignable en utilisant une technologie basée sur la fibre de verre renforcée de polymère (FRP). Le rapport de la RCCAO recommande également la recherche de méthodes de livraison susceptibles de régler les problèmes croissants de retards dans la construction et la réparation des infrastructures. Cet objectif peut être atteint grâce à l'utilisation de techniques utilisant des éléments préfabriqués et des raccordements afin d'accélérer le remplacement des ponts, pour réduire la fermeture des voies et l'émission de gaz à effets de serres dans le transport.

L'utilisation d'éléments et de systèmes préfabriqués dans la construction des ponts a récemment attiré l'attention et l'intérêt des gouvernements responsables des ponts aux USA et au Canada, qui y voient une façon d'améliorer la construction des ponts. Grâce à la production en série des matériaux, à la réutilisation des coffrages, à la réduction de la main d'œuvre sur le chantier et à la concentration des travaux de construction dans une usine plutôt que sur le chantier des ponts, il est possible de réaliser d'importantes économies. Les problèmes reliés à la sécurité sur les aires de travail et aux perturbations de la circulation sont aussi des problèmes importants. La fermeture d'une voie coûte très cher sur les autoroutes urbaines à cause de l'impact économique important sur les activités industrielles et commerciales. Les éléments et les systèmes préfabriqués peuvent être assemblés rapidement, ce qui diminue l'impact sur l'environnement autour du chantier et

suite à la page 31

PRESIDENTIAL PERSPECTIVE / PERSPECTIVE PRÉSIDENTIELLE

V.H. (VIC) PERRY FEC, FCSCE, MASC., P.ENG. / FEC, FSCGC, MASC., ING.

The JOURNEY along the ROAD MAP to VISION2020 — "*LEADERSHIP IN SUSTAINABLE INFRASTRUCTURE*"

It is an exciting time to be a civil engineer and member of the CSCE as our organization evolves. As civil engineers and keepers of the infrastructure, we have an obligation to society to ensure that our infrastructure is built in the most sustainable way. The CSCE has a role to play in helping civil engineers deliver on their obligation to society by showing leadership in sustainable infrastructure.

While the "Road Map" to Vision2020 is a work in progress, under the leadership of our President Elect, Randy Pickle (email: RPickle@morrisonhershfield.com), there are many CSCE activities underway that are well aligned with our vision. The road map is currently in draft and being discussed, debated, reviewed and re-drafted, with a delivery date of June 2011 to the CSCE Board of Directors and then the membership. The team responsible for putting this together is a group of past, present and future presidents, committee chairs, board members, members at large and headquarters staff, who are all enthusiastically contributing to the success of CSCE's road map.

The current CSCE structure of committees and headquarters has historically provided excellent programs for our membership. Many of these programs are highly successful and will continue with minor alignments towards our new vision. Actually, most of the current committees and programs have already identified and modified their alignment. This has been a result of the input and dialogue process along with the normal evolution towards a more sustainable society over the past year and a half.

The following list of activities or programs provides examples of how CSCE is changing and evolving towards our vision:

- A new Report on Infrastructure,
- A common language to communicate on infrastructure,
- Increased communications on Sustainable Infrastructure issues,
- Increased contact with Infrastructure & Transport Canada at the ministerial level,
- Increased number of collaborations with other organizations who have common goals on infrastructure,
- A White Paper on Sustainable Infrastructure,
- Cross Canada Town Hall Meetings on defining Sustainable Infrastructure,
- A new Young Professionals Group,
- A new Award for Leadership in Sustainable Infrastructure,
- History Awards recognizing examples of Sustainable Infrastructure, and

Sur le chemin menant à VISION2020 — « *POUR UN LEADERSHIP EN INFRASTRUCTURES DURABLES* »

C'est une période fascinante pour l'ingénieur civil et le membre de la SCGC, dans la mesure où notre organisme évolue rapidement. À titre d'ingénieurs civils responsables des infrastructures, nous avons envers la société l'obligation de voir à ce que nos infrastructures soient construites de la façon la plus durable possible. La SCGC a un rôle unique à jouer pour aider l'ingénieur civil à s'acquitter des ses obligations envers la société en faisant preuve de leadership en matière d'infrastructures durables.

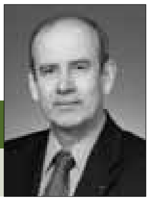
Même si le plan qui mène à Vision2020 demeure un travail en cours de réalisation, sous le leadership de notre président désigné, Randy Pickle (courriel : RPickle@morrisonhershfield.com), nombre d'activités présentement en cours à la SCGC nous rapprochent de notre objectif. Ce plan est présentement à l'étude et fait l'objet de discussions, de débats, de nouvelles versions, et devrait être soumis en juin 2011 au c.a., et, par la suite, aux membres. L'équipe responsable de ce travail est formée de présidents d'hier, d'aujourd'hui et de demain, de présidents de comités, de membres du c.a., de simples membres et de permanents. Tous sont fiers de contribuer au succès de cette importante démarche.

La structure actuelle de la SCGC, avec ses comités et ses bureaux, a, dans le passé, fourni d'excellents programmes à nos membres. Nombre de ces programmes sont de grandes réussites et continueront, avec de légères adaptations en fonction de nos nouveaux objectifs. En fait, la plupart de nos comités et programmes actuels ont déjà défini et adapté leur orientation. Cette réorientation a été le résultat d'un dialogue et d'une évolution normale vers une société plus durable, au cours des 18 derniers mois.

La liste d'activités ou de programmes ci-dessous illustre comment la SCGC évolue en fonction de l'idéal que nous nous sommes donné :

- Un nouveau rapport sur les infrastructures,
- Un vocabulaire de base commun à tous pour parler d'infrastructures,
- De meilleures communications sur tout ce qui concerne les infrastructures durables,
- De meilleures relations avec Infrastructures et Transport Canada, au niveau ministériel,
- Plus de collaboration avec les autres organismes qui partagent les mêmes objectifs en matière d'infrastructures,
- Un Livre blanc sur les infrastructures durables,
- Des assemblées publiques à travers le pays sur la définition des infrastructures durables,
- Un nouveau groupe de jeunes professionnels,
- Un nouveau prix pour le leadership en matière d'infrastructures durables,
- Des prix d'histoire pour souligner les exemples d'infrastructures durables, et
- Des programmes techniques de comité sur le thème de la durabilité.

Ce numéro de L'ICC a pour thème « La construction des ponts en accéléré ». Bien que ce thème puisse paraître, à première



- Technical committee programs with a sustainability theme.

The theme for this issue of the Canadian Civil Engineer is “Accelerated Bridge Construction (ABC)”. While this may at first appear to be counter intuitive to sustainable infrastructure, it is in fact strongly supporting sustainability when understood as “Get-in, Get-out and Stay-out”. Bridges provide a critical link to our transportation networks and minimizing “out-of-use” or road closures is very important to reducing congestion and traffic disruption. The environmental impact of traffic delays is significant and detours, for even short periods, can generate as much extra vehicular CO_2 emissions as the embodied bridge materials. Furthermore, building more durable, long lasting structures is one of the defining properties of sustainable infrastructure.

Please send me your comments or suggestions at email; president@csce.ca

vue, en contradiction avec l’idéal de durabilité des infrastructures, il s’agit en fait d’une démarche en faveur de la durabilité, vue sous l’angle « construire au plus vite pour en sortir au plus vite ». Les ponts assurent un lien capital dans nos réseaux de transport, et l’élimination des fermetures de routes est très importante lorsqu’il s’agit de diminuer la congestion des routes et le blocage de la circulation. L’impact sur l’environnement des problèmes de circulation est important, et les détours imposés, même pour de courtes périodes, peuvent créer la production par les véhicules de plus de CO_2 que les matériaux du pont. En outre, construire des charpentes plus durables constitue l’une des qualités recherchées dans les infrastructures durables.

Faites moi parvenir vos commentaires et vos suggestions à l’adresse suivante : president@csce.ca

2011 ANNUAL GENERAL MEETING OF THE CSCE

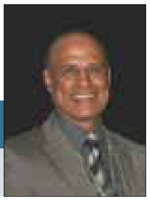
The 2011 Annual General Meeting of the Canadian Society for Civil Engineering will be held during the Annual Conference of the Society on Thursday, June 16, 2011 at the Westin Hotel in Ottawa, ON. This meeting will receive the Annual Report of the Society including that of the President, the reports of the Technical Divisions, Regional Coordinating Committee, Administration Coordinating Committee, Programs Coordinating Committee, Official Auditors and will consider such other business as may come before the meeting.

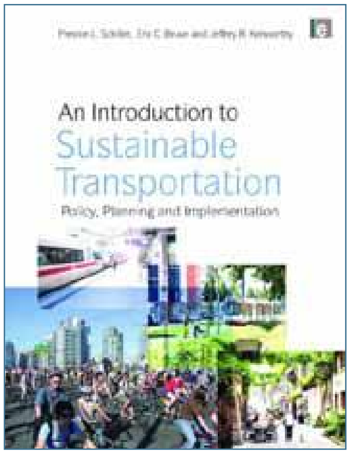
ASSEMBLÉE GÉNÉRALE ANNUELLE 2011 DE LA SCGC

L’assemblée générale annuelle 2011 de la Société canadienne de génie civil aura lieu pendant le congrès annuel de la société, jeudi le 16 juin 2011 à l’hôtel Westin à Ottawa, ON. Lors de cette assemblée seront soumis le bilan annuel de la société, incluant le rapport du président, les bilans des divisions techniques, des conseils régionaux, des comités de coordination de l’administration, des comités de coordination des programmes, du vérificateur et tout autre sujet soumis à l’assemblée.

BOOK REVIEW / LIVRES

SAID M. EASA PH.D., P.ENG., RYERSON UNIVERSITY





"An Introduction to Sustainable Transportation: Policy, Planning, and Implementation"

Authored by Preston L. Schiller, Eric C. Bruun, and Jeffrey R. Kenworthy, Published by Earthscan, London, 2010, pp 342.

This important book by Schiller, Bruun, and Kenworthy is timely and unique. It is timely as sustainability has been the prevailing concern of transportation planners and policy-makers during the past decade, especially regarding infrastructure. It is unique in terms of the broad sustainable transportation (ST) domains that are beautifully integrated and supplemented with examples from around the world. This integration is the central theme of the book which well fits its title. The book is written for people without advanced education in mathematics, engineering, or physical sciences. Before discussing other special features of the book, it is useful to present highlights of various chapters.

The book consists of ten chapters. Chapter 1, *A Highly Mobile Planet and its Challenges*, discusses the definitions of ST and explores two challenges confronting this phenomena. One is automobile dependence (environmental, economic, and social problems) and the other is inequity, which is often not considered in ST discussions. The authors provide an in-depth look at how inequities, as related to auto dependence, arise from the lack of not only mobility, but also accessibility. Chapter 2, *Automobile, Cities, the Car Culture, and Alternative Possibilities*, builds on the previous chapter by exploring how a car culture has developed from walking cities to transit cities and then to automobile cities (both urban and suburban areas). The evolution of these city types is clearly illustrated using schematic diagrams. The chapter ends with an intriguing illustration of the contrast between car-dependent and car-free families.

Chapter 3, *History of Sustainable and Unsustainable Transportation*, presents a purview of land modes, water travel, aviation, and telecommunications along with infrastructure development during the past two centuries. The reader will be able to grasp the time period over which transportation innovations have occurred for several modes and the rapidity of the pace of change. For the novice there is much to be learned here. Chapter 4, *Modes, Roads, and Routes,* compares the characteristics of various transportation modes, including futuristic modes. The comparison tables provided are quite useful and the authors are commended for addressing this complex task. Chapter 5, *Moving Freight, Logistics, and Supply Chains in a More Sustainable Direction*, presents key aspects of freight transportation which is often a neglected area in ST strategies.

Two important aspects that should be considered in policy and planning for ST are addressed in Chapter 6, *Transportation Economics and Investment*. This chapter reviews basic economic analysis methods and suggests ways for integrating improved methods within public policy, project evaluation, and investment decisions. The concept of life-cycle analysis is briefly addressed. Chapter 7, *Public Policy and Effective Citizen Participation*, examines how transportation policy and public participation can interact with and help ST efforts. The authors provide examples of the roles played by political leadership and well-informed citizens in several cities.

What is interesting about Chapter 8, *A New Planning Paradigm*, is its logical structure that lively transitions the reader from the 'Business as Usual' (BAU) planning to a new ST paradigm. The chapter opens with lessons learned from the preceding chapters. It then presents a new paradigm for integrating various planning elements with policy making and participation reforms. The concept of 'mobility management' (managing existing resources and services) is introduced. The notion of 'going beyond' ST planning to the repair, regeneration, and renewal of the physical, social, and cultural environments, and governance and decision-making institutions is also addressed. The book then presents an agenda and priorities for ST.

Chapter 9, *Examples of Sustainable Transportation*, reviews ST efforts in six cities with different sizes and very different socio-economic and cultural characteristics. It looks at the key successes and how they were achieved, and provides some quantitative snapshots of each city. These examples cover many of the issues and approaches of the new proposed paradigm. Chapter 10, *Conclusion,* discusses the most vital actions, preparations, and measures that are needed to move from conventional BAU planning to sustainability. Threads and themes drawn from successful ST examples are presented. The authors argue: "*At the end, people must experience and feel the difference between automobile transportation and sustainable transportation-based ways of life, and the kind of overall environment and 'lifestyle packages' that this can create*" (p. 310). As nearly a non-automobile user for ten years, I personally attest to this statement.

Besides its goal of shaping planning, policy-making, and citizen activities in a sustainable direction, this book is also a synthesis that draws together a huge amount of technical, social, economic, environmental, and cultural material. Much of the material involves research conducted by Schiller, Bruun, and Kenworthy who have diverse backgrounds that have enriched the book contents. Another nice feature of the book is the 'boxes' that are frequently inserted in each chapter. The boxes include vignettes that provide details or illustrative

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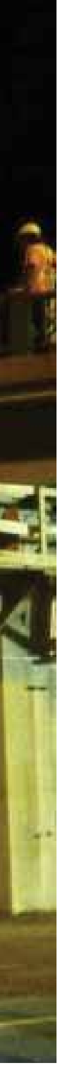
Implementation of Prefabricated Bridge Technology in Ontario

INTRODUCTION

The Ministry of Transportation of Ontario (MTO) has adopted the use of prefabricated bridge technology as a mainstream approach to bridge construction and rehabilitation. The need for this new technology has been spurred on by numerous factors such as ever-growing traffic volumes brought about by an increasing population, rising need for new and rehabilitative bridge construction due to an ageing infrastructure, escalating user costs caused by endless construction-related traffic delays. To address these issues, MTO initiated a research study in 2000 to study the feasibility of constructing/rehabilitating bridges using prefabricated bridge systems/elements.

It was recognized early on that one of the main challenges would be to develop a simple yet durable detail for the joint system that would link the precast components together. A conscious decision was then made to adopt a joint detail that would involve some minimal in-situ concreting to provide the desirable monolithic connection between the precast elements. Two types of bridge systems (Figure 1) were selected for the experimental study. The first system (A) consists of fabricating precast T-shaped girders, installing them at the site and casting in-situ concrete closure strips to complete the bridge superstructure. This method of construction is well suited for single span or multiple span structures with



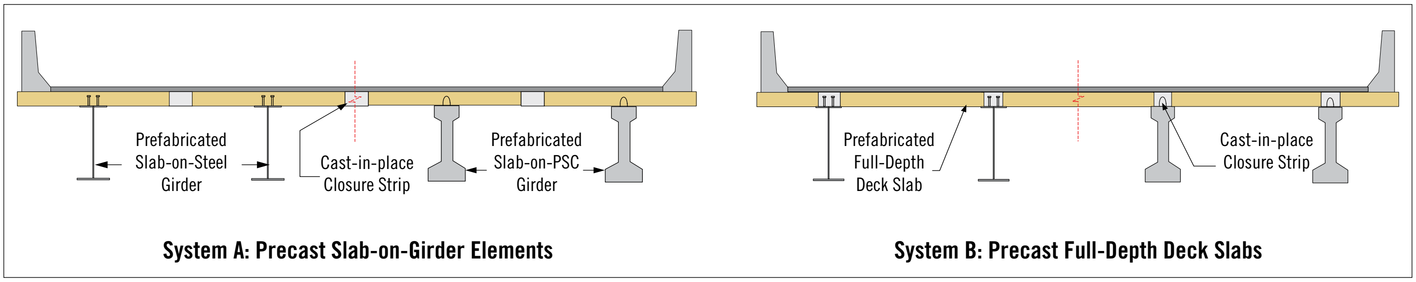


FIGURE 1: Prefabricated Bridge Systems Considered by MTO.


Steel Piles Driven
Precast Abutment Unit
Concrete Closure Pour

FIGURE 2: Precast Abutment Unit.

FIGURE 3: Precast Wingwall Unit.


Precast Beam Installed
Precast Beams Assembled
Closure Strip Details
Closure Strips Cast

FIGURE 4: Precast Beams Linked by Closure Strips.

semi-continuous connections at the piers. The limitations of this approach are the transportation and erection of the potentially heavy T-beams. The second system (B) consists of fabricating sections of full-depth slab decks, installing at the site on top of steel or prestressed concrete girders and pouring the closure strips over the girders and between adjacent panels to complete the superstructure. Since the slab sections can be fabricated in smaller sizes, the difficulty related to transportation and erection of larger components can be overcome by the use of this system. The latter is also more suitable for longer span bridges or bridges with continuous spans.

FIELD APPLICATIONS

The encouraging results obtained from the experimental research study provided the ministry with the confidence to move forward with the initiative to adopt prefabricated bridge technology as a mainstream approach for new bridge construction and rehabilitation. The first fully prefabricated bridge project was implemented in 2004 for the replacement of the Moose Creek Bridge on Highway 101. Following a successful implementation of this first trial project, the Ministry has since used this innovative technology in over 20 bridge projects, with about another 40 projects currently on the drawing board. The following describes a few typical applications of the technology in recent MTO projects.

Moose Creek Bridge, Hwy 101

This bridge was constructed in 2004 using prefabricated elements for both substructure and superstructure. The superstructure was made up of prefabricated prestressed slab-on-girder beam elements (T-shaped beams) and the substructure was constructed with prefabricated abutment segments and wingwalls. The structure was a single-span integral abutment bridge, 22 m long, with an overall deck width of 14.64 m and carries Hwy 101 over Moose Creek east of Timmins in Northern Ontario. The substructure was made up of three precast segments (Figure 2), which were connected together with 600 mm wide cast-in-place concrete closure strips between segments. Each segment was supported on two pre-driven steel H-piles and connection was made through 600 mm by 800 mm pockets formed into the base of the segments, which were then filled with insitu concrete. The substructure was completed with two precast wingwalls (Figure 3). The deck system consists of six precast prestressed T-shaped beams that were connected together on site using a 300 mm wide cast-in-place concrete closure strip (Figure 4). A special nib detail was incorporated into the beam flanges to allow the closure pour to be cast without any additional formwork requirement. Normal concrete was used to fill all the closure strips and pockets.

Little Savanne River Bridge, Hwy 17

This bridge was constructed in 2005 using full-depth precast deck panels that were made composite with pre-installed steel I-girders through shear studs welded into rectangular pre-formed pockets in the deck panels. The structure is a three-span continuous bridge with integral abutments and carries Hwy 17 over Little Savanne River east of Upsala in Northwest Ontario. The spans are 14.5 m, 19.0 and 14.5 m in length and the overall deck width is 13.75 m. The deck is 225 mm thick and is supported on six steel I-girders spaced at a regular spacing of 2.27 m. The deck system was made up of twenty precast full-depth deck panels

FIGURE 5: Installation of Full-Depth Deck Panels.

FIGURE 6: Closure Strips between Deck Panels.

FIGURE 7: Shear Studs in Preformed Pockets.

that were laid out in a 5x4 grid (Figure 13) and were connected by a longitudinal cast-in-place concrete closure strip, 500 mm wide, at the centreline of the roadway and four transverse closure strips, 650 mm to 800 mm in width (Figures 5 and 6). The slab panels were made composite with the supporting girders through shear studs welded into preformed rectangular pockets in the deck panels (Figure 7). Each deck panel had three shear pockets except for the panels over the pier locations, which had four. A curb detail was incorporated into the exterior deck panels to which a box beam guide rail system was later attached. Continuity over the piers was provided by deck panels that were designed for the required live load moments. Normal concrete was used to fill all the closure strips and shear pockets.

FIGURE 8: Precast Panels Lifted from Truck.

Mull Road Underpass, Hwy 401

This bridge was rehabilitated in 2006 with a new concrete deck using full-depth and full-width prefabricated deck panels that were cast at a nearby precasting yard and transported to the site for installation on top of the existing girders. The structure originally consisted of four simply-supported spans and carries traffic on Mull Road over Highway 401, about 20 km east of Chatham-Kent in Ontario. The spans are 12.19 m, 18.59 m, 18.59 m and 12.19 m in length and the overall deck width is 11.277 m. The new deck slab features an innovative debonded link slab system that provides slab continuity over the pier locations, while the existing five steel girders remain simply supported.

The deck system was made up of twenty three precast full-depth and full-width deck panels (Figures 8 and 9) that were connected transversely by 300 mm wide cast-in-place concrete closure strips (Figure 10). Barrier walls were also precast at the ends of the deck panels. The precast full-depth deck panels were typically 2,300 mm wide and the deck slab was made semi-continuous for live load at the pier locations by a prefabricated link slab segment, approximately 2.4 m to 3.0 m wide, which was debonded from the top flange of the I-girders. Continuity of the longitudinal reinforcement for the link slab panel was provided by mechanical couplers inside the closure strips. Composite action was provided by shear studs located in preformed shear pockets in the deck panels (Figure 10), which were later grouted while normal concrete was used to fill all the transverse closure strips.

CPR Overhead @ Morriston, Hwy 6

The Ministry has also used prefabrication for smaller structural components such as pier caps as shown in this example. The structure is a three-span continuous bridge, 51.5 m long, with an overall deck width of 14.78 m and carries Hwy 6 over CP railway near Morriston, Ontario. The deck system consists of precast voided box girders supported on two interior concrete pier systems. The pier caps were prefabricated on-site in two segments, 9.5 m and 4.47 m long. They were lifted and placed on three new cast-in-place circular concrete columns and then joined together with a 930 mm wide closure pour (Figure 11).

FIELD PERFORMANCE

Based on the latest visual inspections of the prefabricated bridge projects implemented so far by the ministry, all the structures are performing well structurally. No evidence of cracking at the top of the asphalt wearing surface has been observed and there has been no visual sign of water leakage through the closure strips at the soffit level for all the bridges that were waterproofed and paved. Minimal hairline cracking was observed along the cold joints in some of the bridges that have been closely inspected. Hairline transverse cracks were also observed at the soffit of some of the closure strips, and were due to shrinkage of the concrete in

FIGURE 9: Installation of Full-Width Deck Panels.

FIGURE 10: Closure Strip & Shear Pockets.

Precast Pier Cap CIP Column Bearing Pads Pier Cap Installed

FIGURE 11: Sequence of Construction of Precast Pier Cap.

the closure pours given the large length to width aspect ratio of the closure strips. To further validate the prefabricated bridge systems, a proof load test was carried out in 2006 on the Little Savanne Bridge on Hwy 17. The results showed that the structural performance of the bridge was excellent and better than predicted theoretically. Excellent and consistent composite action was also observed between the prefabricated deck panels and the supporting steel girders.

CONCLUSIONS AND FUTURE DIRECTIONS

Based on the experience obtained from the prefabricated bridge projects that the ministry has carried out since 2004, the following conclusions and recommendations can be made:

(1) The two prefabricated bridge systems advocated by the ministry are performing well from a structural standpoint and there is no cause for concerns with regards to their long-term durability and performance. With the ministry policy of waterproofing and paving all bridge decks, water leakage issues at the cold joints should not be of concern.

(2) Based on construction costs alone, prefabricated bridges are more expensive than conventionally-built ones. This situation should improve as the technology matures and competition in the marketplace creates more suppliers/fabricators than currently available. However, due to the shorter construction time frames, the higher constructions costs are easily offset by reduced traffic control and road-user costs.

(3) To fully tap into the benefits of bridge prefabrication, improvement in the concrete material used in closure strips is needed to speed up the turn-around time required for the bridge to re-open for traffic. To that end, a new concrete mix has recently been designed to provide high early strength (36 MPa within 8 hours) that will significantly shorten the curing time of the closure pour concrete. Field applications of this new product have already taken place with encouraging results.

(4) To further promote bridge prefabrication and standardisation as a means to accelerate the bridge design and construction process in Ontario, work is currently under way on the development of a standard bridge design manual. This document is aimed at standardising designs for bridges with most commonly occurring deck widths (10 to 22 m) and span lengths (10 to 46 m). The manual will cover bridges constructed with prestressed concrete girders (CPCI), steel girders with wide flange sections (W), welded wide flange sections (WWF) and reduced wide flange sections (WRF) for single and two span cases. As well, the manual will provide suitable details for precast full-depth concrete deck slabs, standard panel layout configurations and joint details. The manual will be applicable to both cast-in-place (CIP) and precast concrete deck slabs. A segment of the manual also covers standard prestressed T-shaped concrete girders (based on CPCI sections) for spans up to 40 m in length. The bridge types, span, and roadway widths chosen will be applicable to almost 60 to 70 percent of bridges constructed on Ontario's provincial highways. ■

FIGURE 1: Island Park Drive Overpass

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Bridge Rapid Replacement with Self-propelled Modular Transporters

INTRODUCTION

Highway 417 is a major freeway running through the City of Ottawa, Ontario, Canada. Constructed between 1959 and 1967, the freeway carries more than 150,000 vehicles each day. Five of the twin bridges carrying eastbound and westbound traffic along the corridor are nearing the end of their expected lifespan with severe deck deterioration and are in need of rehabilitation or replacement. The Ontario Ministry of Transportation (MTO) retained McCormick Rankin Corporation (MRC) to design the replacement of these bridges in conjunction with a major reconstruction/widening of Highway 417.

The replacement was successfully completed at the Island Park Drive Overpass (Figure 1) on August 11–12, 2007 in 17 hours and at the Clyde Avenue Overpass (Figure 2) on August 2–3, 2008 in 15 hours utilizing self-propelled modular transporters (SPMT's).

REPLACEMENT/RENEWAL OPTIONS

The staged replacement of the bridges was considered to be unacceptable to the travelling public as the City of Ottawa does not have alternative routes for this highway and the replacement scenario would have to be accommodated within the highway right-of-way.

The Ministry was looking for an "out-of-the-box" solution and was considering constructing replacement bridge superstructures off-site and sliding or installing them at each bridge. However, there was no off-site location that would suit all five bridge sites. The Ministry therefore started to consider the use of rapid replacement techniques. After 2 years of evaluation and risk assessment, and with the experience gained in this technology in other jurisdictions, it was decided to first undertake a pilot rapid replacement project to replace the twin superstructures at the Island Park Drive site using SPMTs. This was to be followed by the remaining four twin bridges.

FIGURE 2: Clyde Avenue Overpass.

NEW SUPERSTRUCTURES

The new twin superstructures at Island Park Drive each consist of eight (8) welded wide flange 865 mm deep girders spanning 24.70 m centre to centre of bearings and constructed on a 50° skew with conventional reinforced concrete abutments supported on steel piles. The new girders were at the same spacing and in the same longitudinal axis as the existing girders. A conventional 225 mm thick, 18.14 m wide, deck was provided with stainless steel reinforcement being provided in the top mat and in the traffic barriers while black reinforcing steel is provided in the lower mat of the deck.

The Clyde Avenue Overpass consisted of twin slab-on-steel girder superstructures spanning 21.92 m and constructed on a 30° skew with conventional reinforced concrete abutments supported on bedrock. The existing abutments were widened by 5.125 m in order to accommodate an additional traffic lane on Highway 417. The new superstructures each consist of 10 welded wide flange 820 mm deep girders spaced at 2.065 m on centres and spanning 21.55 m centre to centre of bearings. The new deck is 225 mm in depth and 21.025 m wide with the same steel reinforcement as Island Park Drive Overpass.

DESIGN CHALLENGES AND INNOVATION

The replacement of the existing superstructures presented several design challenges requiring innovative solutions.

SEMI-INTEGRAL CONVERSION — Initial survey data indicated that the clear dimensions between the ballast walls of the existing east and west abutments, constructed in 1959, varied by as much as 90 mm. It was concluded that manoeuvring the SPMT's between the ballast walls, during replacement of the superstructures, represented a high risk with potential delays associated with jamming of the new superstructures on the loaded SPMT's. Accordingly, it was deemed necessary to completely remove the existing ballast walls to provide maximum flexibility for proper fit-up on the night of the rapid lift. This provided the considerable added benefit of being able to make the new bridge superstructures semi-integral with the bridge approach slabs thereby eliminating the bridge expansion joints. This results in a structure with a longer service life and lower maintenance costs.

A methodology was therefore developed to sawcut the existing ballast walls on weekends a few weeks in advance of the rapid lift operation with temporary lane closures. This included the staged removal of the existing approach slabs, excavation of granular materials behind the ballast walls and the use of a 1,500 mm diameter track mounted saw to cut through the existing 610 mm thick ballast walls. The existing ballast walls had been temporarily secured in place against each girder using steel plate supports welded to the existing steel girders and anchored into the concrete ballast walls and were shimmed following sawcutting operations (Figure 3). The ballast walls were subsequently removed with the superstructure as part of the rapid lift replacement operations. Upon completion of the sawcutting operations, granular backfill and temporary pavement were used to restore the traffic lanes into service. Finally, new semi-integral details for the deck diaphragms were developed to suit the rapid replacement (Figure 4).

ADJUSTABLE BEARINGS — The finishing of 16 individual bearing seats at each abutment of the Island Park Drive Overpass to a specified theoretical elevation and then placing new superstructures that would bear 100% true at each bearing location was deemed to be practically impossible. The relatively stiff deck and girder framing arrangement given the girder spacing and relatively short span of the structure raised further concerns with respect to the transverse flexibility and ability to deflect differentially at each bearing location.

An adjustable bearing system was developed to solve this problem thus ensuring a precision fit at each bearing seat and minimizing potential cracking in the deck associated with different support conditions (Figures 5 and 6). The use of stainless steel shims, with thickness requirements at each bearing location predetermined in advance by means of accurate surveying, proved to be a key solution as it provided the Contractor with the ability to ensure true parallelism between the girder shoe plate and supporting steel plate in order to allow the elastomeric bearing pads to fully bear on the adjustable bearing plate.

The use of 4 anchor bolts with adjustable nuts allowed some fine tuning of the final bearing seat elevation to ensure 100% bearing. This system was highly successful as the Contractor spent little time to fine tune the bearing levels and the completed structures were set down in minimal time. The stainless steel shims were subsequently embedded in a concrete overlay thus allowing a neat finish of the permanent bearing seat following the rapid lift operations.

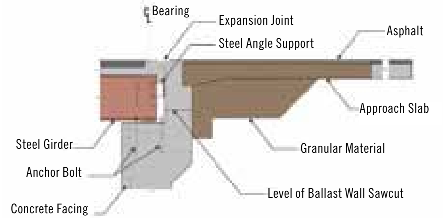

FIGURE 3: Existing Structure/Abutment Details.

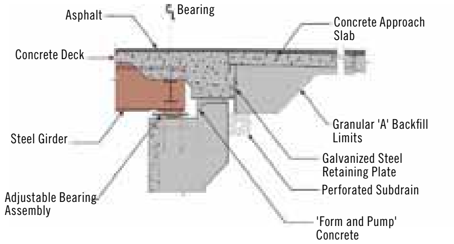

FIGURE 4: Semi-integral Abutment Conversion Detail.

FIGURE 7: New Island Park WB Superstructure.

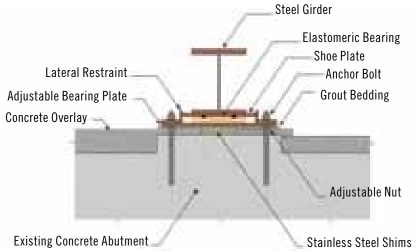

FIGURE 5: Adjustable Bearing Detail.

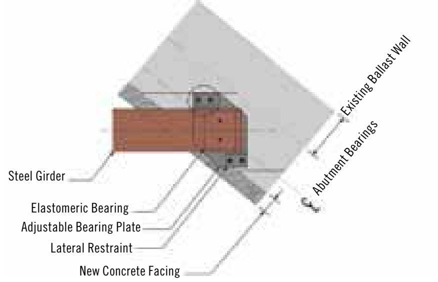

FIGURE 6: Plan View of Adjustable Bearing.

FIGURE 8: SPMT's at Existing Clyde Avenue Bridge.

STRUCTURE DEPTH OPITMIZATION — The location, spacing and depth of the new girders presented a few challenges. It was deemed preferable to offset the new girders from the existing girders to facilitate preparatory work required to construct and install the adjustable bearings from a risk management perspective. This can be more easily achieved at the structures being widened, as the abutment widening permits more flexibility in placing the new girders outward of the existing girders. This was possible at all of the bridges except for the Island Park Drive Overpass where the bridge superstructure was being replaced with a new superstructure of the same width. Placing the new girders outwards of the existing girders would have necessitated that the exterior girder be corbelled from the existing abutment or that the abutment be widened. The new girders were therefore placed in the same location as the existing girders such that the preparatory work for the adjustable bearings, namely the installation of the anchor bolts, had to be undertaken using of U-shaped templates to facilitate locating the anchor bolts on either side of the existing girder. The condition of the bearing seat under the girders was also unknown until the rapid replacement when the existing girders were removed.

The new girders consisted of built-up plates forming a Welded Wide Flange (WWF) section. At the five bridges the depth of the new girders varied from 865 mm to 820 mm. The spacing of the girders was kept the same as the existing at all bridges. It was not possible to alter the spacing without creating conflicts for the location of the anchors bolts, bearing seat and the design of the adjustable bearings.

TEMPORARY SUPPORT OF PREFABRICATED SUPERSTRUCTURES — An adjacent site known as Hampton Park, immediately north-west of the Island Park Drive Overpass was utilized to undertake the prefabrication of the new twin superstructures and to provide the necessary staging area for removal and transportation of the existing and new prefabricated superstructures to and from the bridge site. At the Clyde Avenue Overpass, a snow depository site belonging to the City of Ottawa was utilized to support the temporary structures used for pre-fabricating the new bridges. Similarly, sites close to the bridges will be available for the remaining three structures to be replaced.

The site conditions with the presence of soft clays presented design challenges for the foundations of the temporary structures in the construction staging area at the Island Park Drive Overpass. At the Clyde Avenue site, the temporary structures were founded on bedrock. With the use of "high load" columns and spread concrete footings on engineered granular pads, the Contractor was able to minimize the bearing pressures and hence limit the total and differential settlements. The girders were shored for deck placement operations in order to minimize dead load deflections and to maximize the benefits resulting from composite action.

The design required that the middle series of columns at the temporary support structure be removed following deck placement. Their removal would allow the SPMT's and temporary frames to be placed underneath the prefabricated bridges before lifting them off their temporary supports and transporting them to their permanent location.

CONSTRUCTION

The construction contract for the Island Park Drive and Clyde Avenue Overpasses were awarded, respectively, for $8.9 M and $9.6 M, with the following scope of work:

- Removal of the eastbound and westbound superstructures with SPMT's;
- Construction in designated staging area and installation of new twin superstructures with SPMT's;
- Rehabilitation of existing abutments and wingwalls including widening at Clyde Avenue and installation of a new noise wall system at Island Park Drive;
- Improvements to Advanced Traffic Management Systems (ATMS);
- Illumination of the overpass structures; and
- Roadway improvements on local street.

A similar contract has been prepared for the Carling Avenue Eastbound structure with construction underway and to be completed in 2011. Construction work for the Carling Avenue Westbound and Kirkwood structures are tentatively scheduled to start in 2012. The rapid lift replacement, which involved the removal of two existing steel superstructures and replacement with two new steel superstructures, was completed in less than 17 hours on August 11–12, 2007 at the Island Park Drive Overpass, marking the first and fastest time for bridge replacement on a major freeway in Canada (Figures 7 and 9). The existing 650 tonne twin structures were removed with SPMT's consisting of two trains of modular transporters each equipped with 18 axles and a total of 216 wheels. Similarly, the replacement of the Clyde Avenue overpass twin superstructures was completed in 15 hours on August 2 and 3, 2008 (Figure 8).

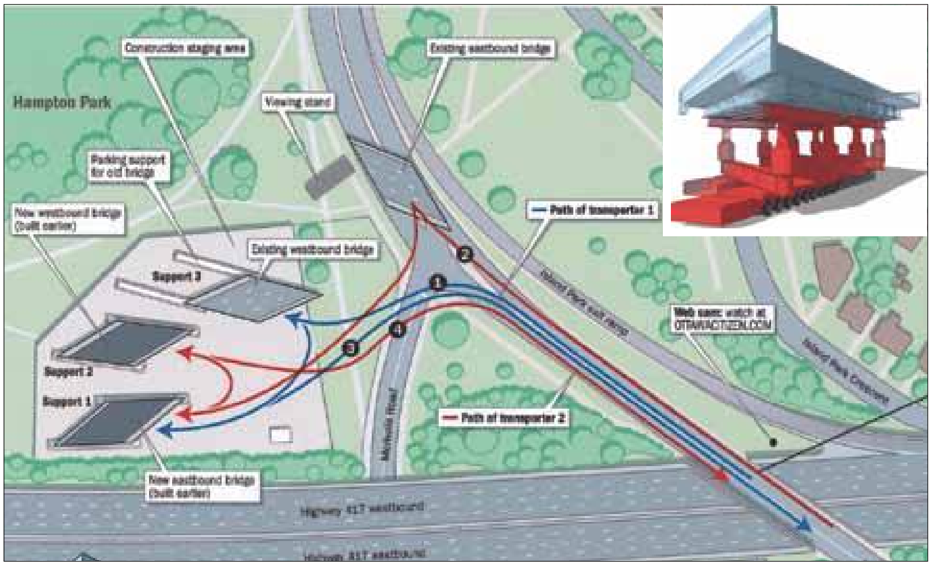

FIGURE 9: SPMT's and Transport Route.

The excavation of granular materials and temporary pavement behind the abutments took approximately 1 hour to complete immediately following closure of Highway 417. The operation was completed simultaneously at the east and west abutments of both structures. The removal of the existing eastbound and westbound superstructures followed and was completed in approximately 4 hours. The transport and installation of the two new prefabricated eastbound and westbound structures took approximately 6 hours to complete. Delays occurred as a result of a minor hydraulic equipment breakdown in preparation for transporting the second superstructure.

Finally, upon completing the installation of the two new superstructures, granular materials were placed behind the new semi-integral abutment diaphragms and paving operations of the bridges with a single

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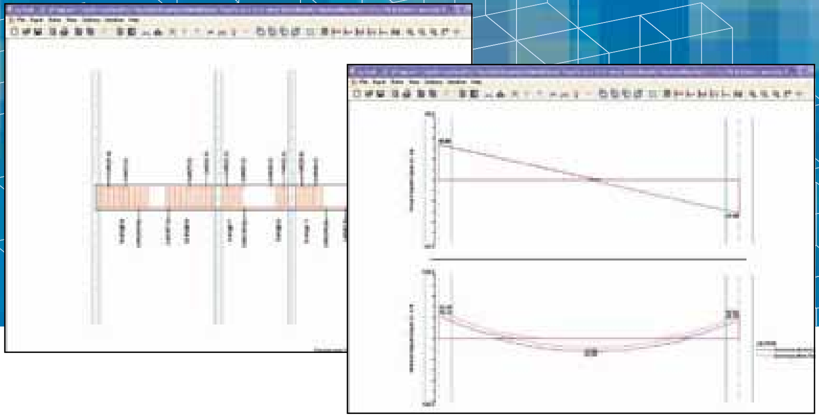

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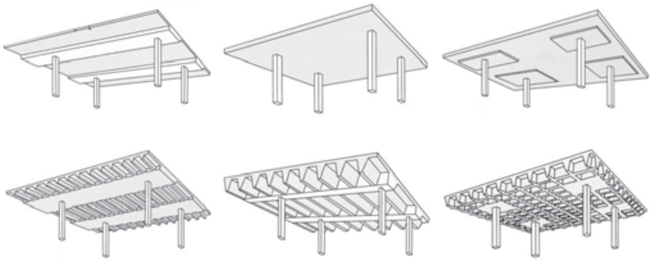

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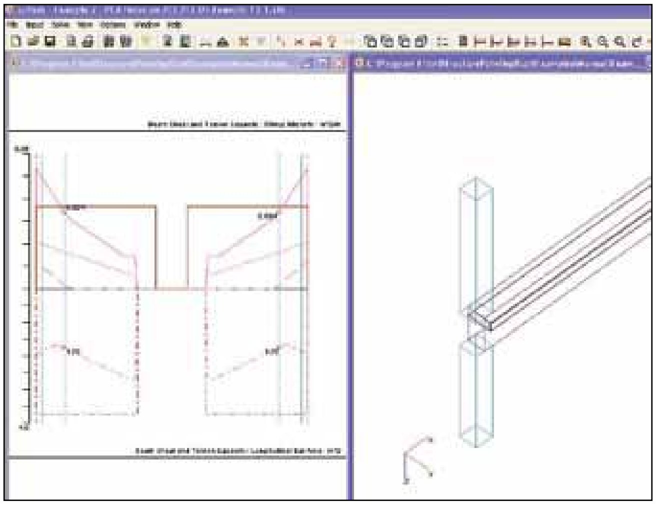

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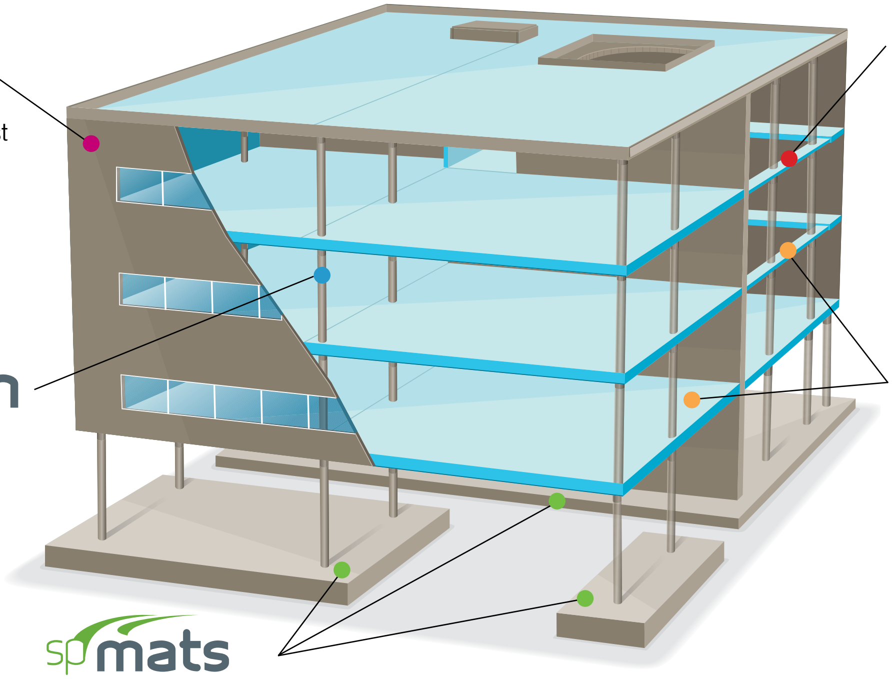

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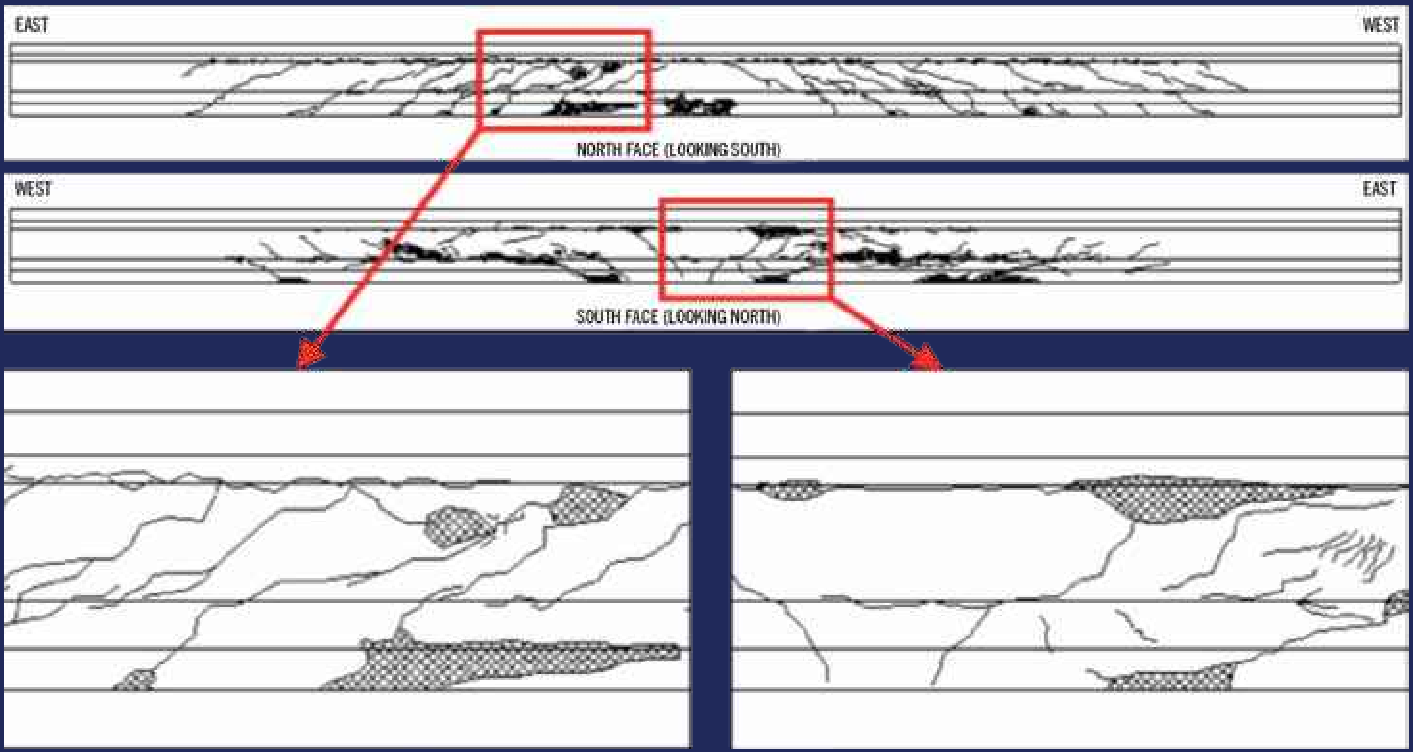

Impact Face

Opposite the Impact Face

FIGURE 1: Crack Mapping of the Damaged Girder.

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Applications of Fibre-Reinforced Polymers in Rapid Repair of Bridge Girders Damaged by Vehicle Impact

A bridge located in Ontario was damaged when a dump truck did not heed height restrictions. The collision caused extensive damage to the girders, which led to the closure of the two-lane bridge. An innovative strengthening scheme, other than the traditional ones, was required to be devised keeping in mind the need to reopen the closed bridge in a short period of time. Replacing damaged or deteriorated bridge girders takes considerable time, human resources, planning and money, not to mention the inconvenience and possible hazards to public life. But are they, or is it, worth rebuilding? The answer is yes, if funds are endless. However, when funding for structure replacement is not usually available, a probable solution lies in the use of fiber reinforced polymers (FRPs).

FRPs contain high-strength fibers embedded in a polymer resin, and are produced as sheets, plates and laminates. They are of extremely light weight and versatile in many applications. They offer resistance to corrosion and are relatively easy to apply. The initial higher expenditure of the FRP system and materials are soon offset by their low installation, and maintenance costs. The use of FRP materials for retrofit and rehabilitation of concrete and steel girders has been investigated by numerous researchers allover the world. This research included various aspects of the behavior such as strength, stiffness,

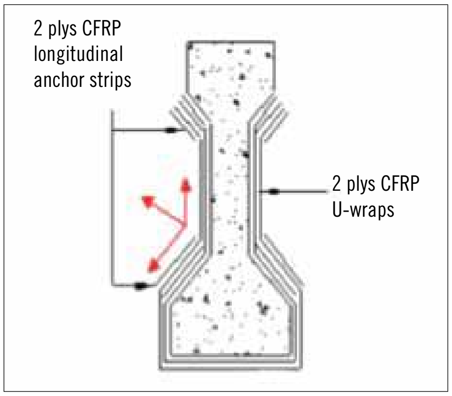

FIGURE 2: Proposed CFRP Arrangement.

FIGURE 3: Final View of the Girder after Application of CFRP Sheets.

FIGURE 4: View of the Rehabilitated Girder after Loading it with 1368 kN Concrete Weights.

ductility and reliability. This has resulted in new provisions in bridge codes, including the Canadian Highway Bridge Design Code. However, many bridge authorities, contractors and consulting engineers are still not satisfied and do not have enough confidence in this innovative material.

Sennah et al. (2007) conducted experiments on the damaged girder mentioned above to establish how practical and useful these FRP materials can be to damaged or deteriorated structures. The girder under investigation was an AASHTO Type-III concrete prestressed girder of 21,895 mm length, and 1,143 mm depth. It acted compositely with a 190 mm deck slab. At the bridge site, the damage girder was saw-cut and the asphalt wearing surface at the top of the concrete slab and the edge concrete barrier wall were removed prior to transporting the girder to a test site in Toronto. Girder inspection, as well as crack mapping shown in Figure 1, showed that the girder suffered irreparable damage and was deemed inappropriate for the structural bridge system it was part of. The collision forced the bottom part of the precast girder to rotate, causing torsion-shear cracks between the girder quarter points, concrete pop out and spalling and horizontal crack between the girder web and top and bottom flange haunches. Concrete spalling exposed the bottom level of steel strands in the bottom flange. However, no damage or cut in the strands was observed.

After the girders were placed over supports at the test site, cracks and spalled areas were cleaned from dust, loose material and any deleterious substances that would mitigate adherence problems. Then, wide cracks and spalled areas were grouted. Sandblasting operations were undertaken to provide smooth and clean surface for the application of CFRP sheets to the girder surface. Then, any apparent surface imperfections and minor pop outs were noted and scheduled to be filled and repaired with epoxy during the stage of carbon fibre reinforced polymer (CFRP) application. Ryerson University research team proposed the repair scheme shown in Figure 2 using strategically-arranged uni-directional CFRP sheets. The sheets were 600 mm wide and placed every 600 mm along the girder length. In order to provide anchorage for these U-wraps at the web-haunch junctions, longitudinal CFRP strips ran along the top and bottom haunches. The strengthening scheme was comprised of four layers: two U-wraps with fibres running vertically and two longitudinal strips with fibres running horizontally. Figure 3 shows view of the girder after completing the CFRP repair process.

The repaired girder was then loaded to the ultimate stage to examine its structural behaviour under higher loads to-collapse. A mobile crane was used for load placement during testing. Uniform load application was achieved using 2.4-ton Jersey barriers and one-ton concrete blocks. The test ended at a total load applied of 1368 kN, when the readings of strain gauges and LVDTs were continuously increasing during the time intervals between two load increments, see Figure 4. The test was terminated at this load level for safety reasons. At about 65% of the total applied loading, sign of new flexural cracks appeared close to the mid-span location. These cracks were propagated towards the concrete slab. However, no concrete crushing was observed at the top surface of the deck slab at the end of the test. However, strain and LVDTs' readings showed that the girder was close to failure.

This load testing is an effective method for evaluating the structural performance of a bridge or its components. This applies particularly to bridges which could not be accurately modeled by analysis, or if the structural response of a bridge to live load is questionable. The 2006 version of the

FIGURE 5: Damage to the Dingman Drive Bridge.

FIGURE 6: Collision-damaged Strands on the Outer Girder.

FIGURE 7: Using the *Grabb-It*® Splice Coupler System to Re-tension Girder Strands.

FIGURE 8: Workers Pumping Self-consolidating Concrete to Reinstate Damaged Girder.

Canadian Highway Bridge Design Code, CHBDC, specifies few methods to determine the ratio between the actual girder live load capacity and the applied factored live load capacity, in terms of the “live load capacity factor”. If the live load capacity factor is more than or equal to 1, the bridge is considered safe with respect to the straining action under consideration (i.e. moment, shear or reaction). In the current research, the experimental live load capacity factor was 2.05. By applying a magnification factor for lateral distribution of loads among girder of 1.579, per CHBDC evaluation provisions, the live load capacity factor was 1.65, compared to 1.49 obtained experimentally. Thus, the proposed rehabilitation methodology could be safely used in similar bridge girders damaged by vehicle impact.

On August 3, 2010, a truck carrying a hydraulic excavator struck the four-span Dingman Drive Bridge over the westbound lanes of Highway 401 near London, Ontario. The truck hit three out of five AASHTO Type-III pre-stressed concrete bridge girders, resulting in extensive damage, see Figure 5. Several innovative products and processes were used to perform the repairs, resulting in cost and time savings for the ministry compared to full girder replacement. Innovations used in the Dingman Drive Bridge repair include: the use of *Grabb-It*® couplers, Self Consolidating Concrete, Carbon Fibre-Reinforced Polymer sheets and a Mobile Barriers Trailer. Bridge repairs were completed by the end of October 2010 through a successful collaborative effort between the Ministry of Transportation (MTO), and service providers.

Developed in the United States, the *Grabb-It*® is a coupler system that permanently reconnects broken strands in bridge girders (Figure 6), to restore the load carrying capacity of the structure, without having to replace the damaged girders. The *Grabb-It*® device is attached to each end of the severed strand and a threaded coupler (similar to a turnbuckle) is tightened, thereby reinstating the prestressing force in the strand. Although MTO has been aware of the *Grabb-It*® system for a number of years, this repair project was the ministry’s first opportunity to use the device. Before the couplers were used on the repair itself, MTO staff practised with the *Grabb-It*® on a model and developed a detailed procedure for the contractor to install the devices. Working with the *Grabb-It*® on site proved more difficult than expected to obtain the desired force in the strands. Force in each strand was determined using a torque wrench to tighten the coupler device and measuring the elongation of the strand. A total of six *Grabb-It*® couplers were installed on two girders, reinstating the pre-stressing force in the girders close to their pre-collision status, see Figure 7.

Self Consolidating Concrete (SCC) was used to repair the damaged concrete girders. SCC is a highly flowable concrete that does not require vibration-based consolidation and can be readily pumped. It is well suited for use where there are tight confines within a given structural repair and concrete consolidation is a concern. Although the installation of *Grabb-It*® couplers caused significant congestion around the exposed prestressing strands and reinforcing steel in the repair areas, the use of SCC resulted in a high quality, durable concrete that required minimal finishing when the forms were removed, see Figure 8. Sheets of woven Carbon Fibre-Reinforced Polymer (CFRP) fabric were placed over the concrete repair areas to further strengthen and protect the girders, see Figure 9. CFRP fabric is light and can be readily attached to the contours of a concrete girder with an epoxy adhesive system. Three layers of CFRP strips were installed on the underside of the girders and evenly spaced vertical strips of CFRP were installed on the webs of the girders using a multi-step process. The proprietary process included diamond grinding all sharp concrete edges, application of a primer and an epoxy putty, rolling the CFRP fabric onto the epoxy putty, coating the CFRP with a saturant and finally covering the entire repair area with an ultra-violet protective coating.

A Mobile Barriers Trailer (Figure 10) was used for the duration of the Dingman

FIGURE 9: Application of CFRP Strips with a Roller.

FIGURE 10: Mobile Barriers Trailer in use at the Dingman Drive Bridge.

Drive Bridge repairs to protect construction workers from freeway traffic. The mobile barrier unit consists of a trailer that is towed into place by a standard truck tractor and then parked to provide worker protection. First used by MTO on a project on Highway 115, the Mobile Barrier Trailer continues to impress contractors and staff in several ministries because of its ease and speed of set-up compared with conventional work zone protection equipment, such as temporary concrete barriers. To minimize disruption to Highway 401 traffic, two of the three westbound lanes were closed on a nightly basis to complete the repairs on the Dingman Drive Bridge. The Mobile Barriers Trailer was removed each morning, opening all lanes during peak traffic hours. The collaborative relationship between ministry staff, consultant and contractors contributed to the successful implementation of new innovations for the repairs. The suite of innovative techniques was well matched to the repair project's needs and improved repair timelines. Also, the use of these innovations significantly reduced costs when compared to full girder replacement. ■

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Accelerated Bridge Construction: Research and Development

The aging highway and municipal bridge infrastructure in Canada is subjected to increasing traffic volumes and must be continuously renewed while accommodating traffic flow. The traveling public demands that rehabilitation and replacement be done more quickly to reduce congestion and improve safety. Conventional bridge reconstruction is typically on the critical path because of the sequential, labor-intensive processes of completing the foundation, and substructure and superstructure components. New bridge systems are needed that allow components to be fabricated offsite and moved into place for quick assembly while maintaining traffic flow. Depending on the specific site conditions, the use of prefabricated bridge systems can minimize traffic disruption, improve work zone safety, minimize impact to the environment, improve constructability, increase quality, and lower life-cycle costs. This technology is applicable and needed for both existing and new bridge construction. Since 2003, an extensive practical-design-oriented research program was conducted at Ryerson University to address the above-mentioned issues.

PREFABRICATED BULB-TEE GIRDER BRIDGE SYSTEM AND CONNECTION TECHNOLOGY

Shah et al. (2007) proposed the use of prefabricated bridge system made of deck Bulb-Tee (DBT) girders as an attractive choice for bridge replacement in Ontario.

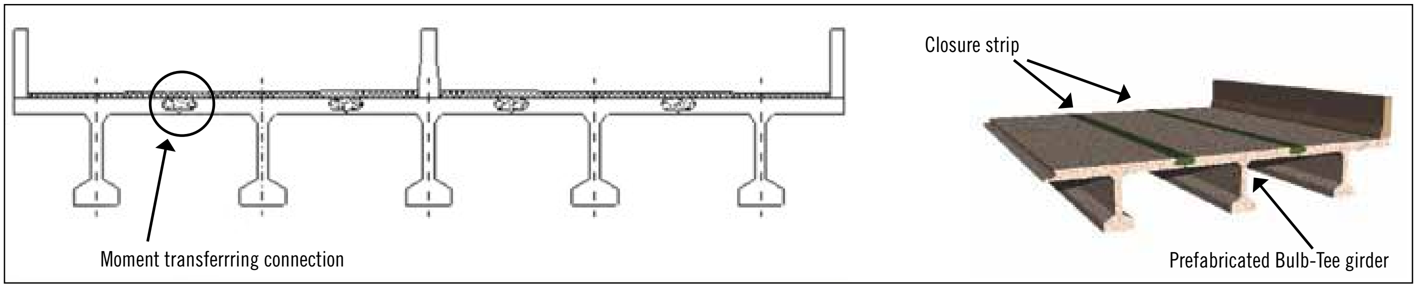

FIGURE 1: Schematic Diagrams of Bulb-tee Girder Bridge System with Closure Strips.

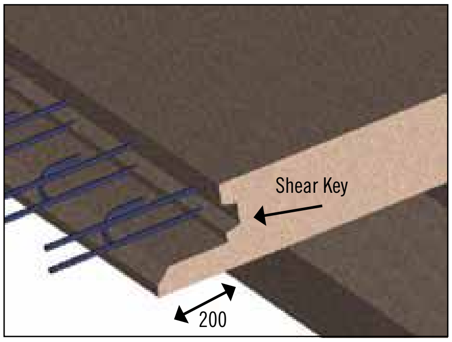

FIGURE 2: Proposed MTC Joint Detail.

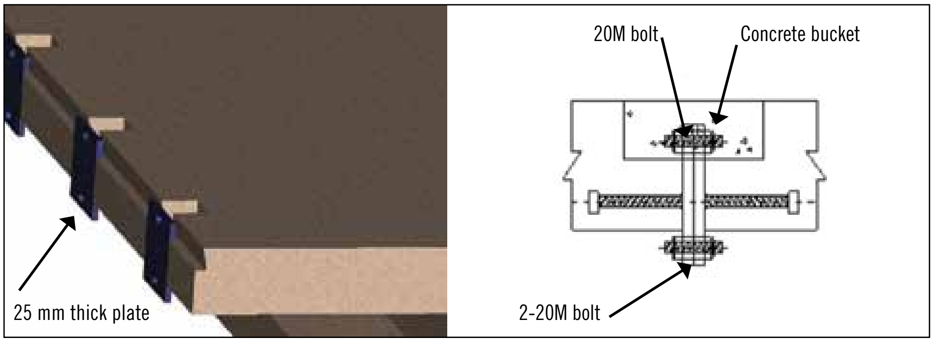

FIGURE 3: Proposed IBC Joint Detail.

In this system, see Figure 1, the concrete deck slab is cast with the prestressed CPCI girder in a controlled environment at the fabrication facility and then shipped to the bridge site. This system requires a closure strip to be poured on site between the precast girders to make it continuous for live load distribution.

The connection between DBT flanges should have specified strength to provide continuity for live load distribution. Based on the information obtained from the literature survey, CHDBC Code and AASHTO-LRFD requirements for design of deck slabs under wheel load, moment-transferring connections (MTC) were developed to maintain the structural integrity of the bridge cross-section and to provide local resistance of the deck slab based on wheel load specification. In order to provide the desirable monolithical connection between precast elements, the connection system involves pouring of a cast-in-place closure strip between the prefabricated girders. Shah et al. developed and tested to-collapse six MTC connection details for the closure strip between flanges of the precast DBT girders. One of these connection details is shown in Figure 2. The moment-transferring connection in Figure 2 has a joint width of 425 mm, which is based on the development length of the 15M straight rebars. Bottom rebars with 180° hook are projecting from the girder flange to be embedded in the cast-in-place joint. The girder flange end is formed with 200-mm wide, 70-mm thick projection slab that acts as a stay-in-place form for the cast-in-place closure strip. Also, the joint has a 75 mm deep, 40-mm wide, trapezoidal shape shear key throughout the girder length. It is assumed that DBT girders will be aligned to provide 25 mm gap that can be filled with a 25-mm diameter foam backer rod.

In addition, Shah et al. (2006) developed four intermittent bolted connection (IBC) details to connect the flanges of the DBT girders. Figure 3 shows one of these connections that joint the girder flanges at 850 mm spacing. Each bolted joint is made of two steel plates 245-mm high, 150-mm wide and 25-mm thick. Each plate is embedded in the concrete deck slab using two 20-mm diameter high strength bolts of length 200 mm. Each steel plate accommodates two holes near its lower end and other one near its top end for A325 M20 bolts. Each bolt hole has a horizontal slot to accommodate any tolerance arising from girder alignments. A trapezoidal grove is made at the top of the girder flange ends to allow for concrete grout after connecting the steel plates. To provide a space to allow for tightening the top bolt firmly, a 100×100×150 pocket is provided at the location of each connecting steel plate. A trapezoidal grove is made at the top of the girder flange ends to allow for concrete grout after connecting the steel plates. Full-size twin-DBT girders of 1,800 mm length and width were constructed with closure strips between them per design. Then, the deck joint was loaded with a patch load simulating the foot print of the CHBDC truck wheel to-collapse, see Figure 4. The developed joint was considered successful if the experimental wheel load satisfied the requirements specified in North American bridge codes prior to failure of the system. Results of experiments showed that most of the connection types satisfied the wheel load specifications. It was concluded that location of the wheel load at the deck slab joint affect the ultimate load carrying capacity of the developed connections.

In continuation of this research to enhance sustainability in the proposed deck joints, Ryerson research team currently investigates the use of glass fiber reinforced polymer (GFRP) bars in these joints in lieu of the epoxy coated reinforcing steel bars. The GFRP-reinforced precast deck slabs incorporates two proposed joints between girder flanges using GFRP headed stud connectors embedded in a closure strip filled with ordinary cement grout and ultra high performance concrete (UHPC), respectively, as shown in Figure 5. The ultimate goal is to reduce the construction

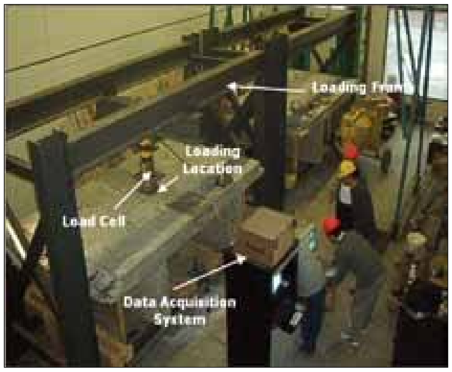

FIGURE 4: View of the Precast Girder Segment During Testing.

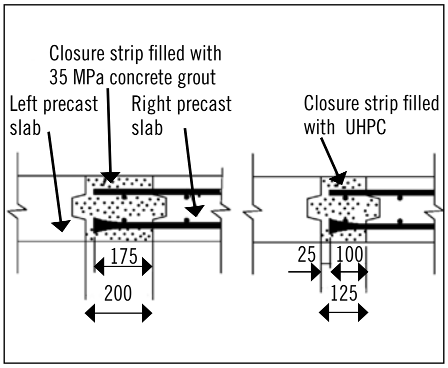

FIGURE 5: Views of Proposed Joint Details Incorporating GFRP Bars with Headed Ends.

time by reducing the width of the closure strip with the use of GFRP with headed ends and ultra high performance concrete (UHPC) to fill the joint. Also, the use of GFRP bars will significantly lower the life-cycle cost as a result of eliminating possible deterioration in bridge decks due to the use of de-icing salt in the winter times. To verify whether the structural performance of those proposed joints is superior and more cost-effective as compared to J-bends incorporating FRP bars with 180° hooks in selected deck panel specimens will also be tested to-collapse. Fatigue behavior and fatigue life of such deck slabs will be investigated using different schemes of cyclic loadings (accelerated variable amplitude cyclic loading as well as constant amplitude cyclic loading). Also, experimental crack width and ultimate load carrying capacity of the tested GFRP-reinforced slabs will be correlated with similar steel-reinforced deck slabs. Results from this research are expected to lead to design procedure for such jointed precast deck slabs with respect to ultimate, serviceability and fatigue limit states requirements specified in the Canadian Highway Bridge Design Code.

LOAD DISTRIBUTION IN PREFABRICATED BRIDGE SUPERSTRUCTURE

With respect to bridge structural analysis, CHBDC specifies simplified method to determine the live load moment and shear in bridge girders and slab bridges in the form of load distribution factors for moment, F_m, and for shear, F_v. Recent software programs available in the market, based on the finite element method, provide more powerful tools to analyze the structure using three-dimensional shell-element models for bridges. Despite the general availability of computers and computer software programs for the bridge analysis, bridge designers in North America strongly prefer simplified methods of analysis to reduce the time spent in design that will be reflected on a considerable reduction in design cost. It was observed that CHBDC simplified method of analysis is applicable to bridges other that the prefabricated bridge system considered for accelerated bridge construction (i.e. bulb-tee girders and adjacent box girders). As such, Ibrahim (2005) conducted a practical design-oriented parametric study on a variety of bulb-tee bridge configurations to determine their moment and shear distribution factors due to the passage of CHDBC truck loading over the bridge. The study yielded more reliable empirical expressions than those available in CHBDC for slab-on-girder bridges.

Bridges built with adjacent precast, prestressed concrete box-girders are a popular and economical solution for short-span bridges because they can be constructed rapidly. The box girders are generally connected by partial-depth or full-depth keyways between each of the boxes, incorporating grouts. Transverse ties, grouted or un-grouted, vary in the form of (i) limited number of reinforcing steel bars with ends embedded in full-depth reinforced concrete edge beams, (ii) a limited number of non-tensioned threaded rods anchored to the out webs of the edge boxes, or (iii) few high-strength tendons post-tensioned in multiple stages. A non-composite concrete topping or a composite structural slab is added. Such bridges have been in service for many years and have generally performed well. A recurring problem, however, is cracking in the longitudinal grouted joints between adjacent box girders, resulting in reflective cracks forming in the wearing surface. This in turn may lead to leakage which allows chloride-laden water to saturate the sides and bottom of the beams, eventually causing corrosion of the non-prestressing reinforcement, prestressing strand, and transverse ties, see Figure 6. In severe cases, complete cracking of joints and loss of load transfer occur.

To improve long-term durability and reduce long-term maintenance, precast "deck free" adjacent box girders can be used in such a way the top flanges of the precast box girders form the final bridge deck surface. In this system, see Figure 7, the precast box girders with thick top flanges are cast in a controlled environment at the fabrication facility and then shipped to the bridge site. Box girders are then placed beside each other over the abutment and piers with 15 mm gaps. This system requires a closure strip to be poured on site between the precast box girders to make it continuous for live load distribution. A shear key is introduced between the adjacent boxes over the depth of the top flange (i.e. 225 mm thick as the thickness of the box's top flange). Lateral bending strength of the closure strip is maintained using U bars projecting from each box's top flange and embedded in a 200 mm width joint. Such durable system has been implemented by Ontario Ministry of Transportation in Ontario bridges since 2006. Figure 8 shows cross-section of the Sunshine Creek Bridge, Hwy 11/17, built with adjacent precast box beams in Summer 2007. While Figure 9 shows views of deck-free precast box beams used in this bridge before filling the closure strips with concrete grout. Other application of this innovative system was used in superstructure replacement of the Eagle River Bridge which forms part of the Trans Canada highway (Rajlic et al., 2010). It should be noted that this top slab of the adjacent precast boxes, along with the closure strip, was reinforced with glass fiber reinforced polymer (GFRP) bars.

CHBDC specifies empirical equations for the moment, shear and deflection distribution factors for selected bridge configurations, including slab-on-girders, multiples-spine bridges, cellular or voided slab bridge and solid slab bridges. However, a simplified method of analysis of adjacent precast concrete box-girder bridge is as yet unavailable. As such, Khan (2010) conducted a parametric study to investigate

FIGURE 6: Types of Distress in Adjacent Box-girder Bridges. (a) Water Leakage through the Joint (b) Efflorescence on Joint Underside (c) Concrete Spalling and Steel Rusting

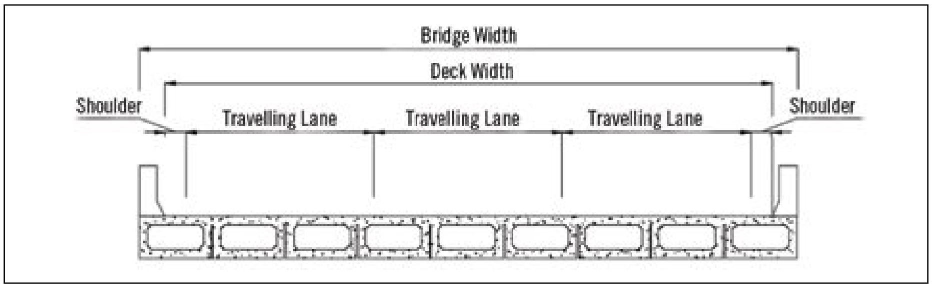

FIGURE 7: View of the Deck-free Precast Box Girders.

FIGURE 8: View of the Adjacent Box Girders used in Sunshine Creek Bridge Hwy 11/17 built in Summer 2007 (courtesy of Pultrall-Trancels Inc.).

the applicability of the simplified analysis method specified in CHBDC for multiple-spine or voided slab bridge configuration to adjacent precast box beams with longitudinal joints that can transfer both bending and shear between each adjacent boxes. In this study, 3D finite element modelling was conducted on wide range of adjacent box girder systems to obtain their moment and shear distribution factors when subjected to CHBDC truck loading conditions. The results showed unfavourable correlation with those available in CHDBC for slab-on-girder bridges, voided slab bridges and multiple-spine bridges. As such, a set of empirical expressions for F_m and F_v values were developed so that bridge engineers can design such prefabricated bridge system more reliably and economically.

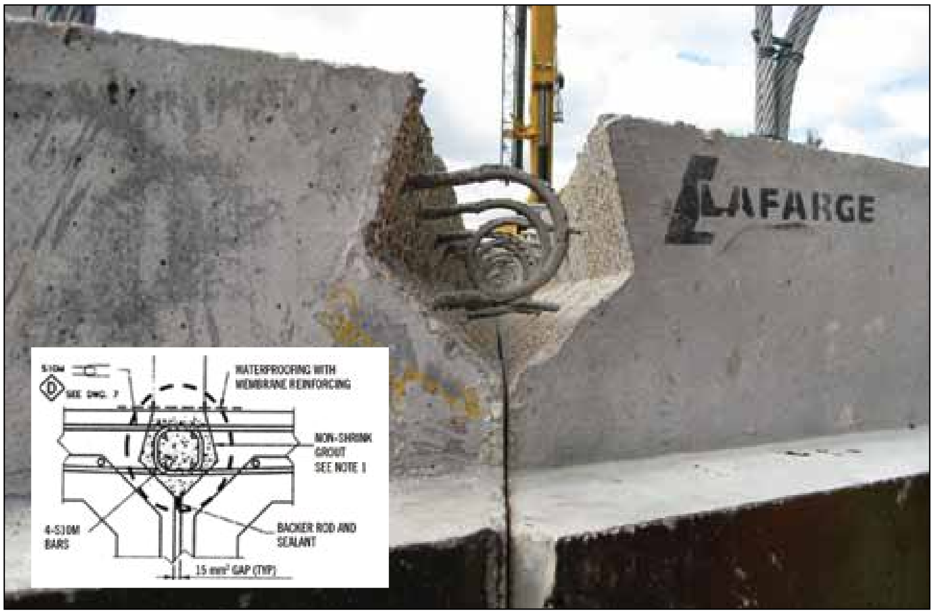

FIGURE 9: Close-up View of the Closure-strip between the Top Portion of Two Adjacent Box Girders in Sunshine Creek Bridge (courtesy of Pultrall-Trancels Inc.).

DEVELOPMENT OF PRECAST CONCRETE BRIDGE BARRIER SYSTEM

In continuation of the efforts of Ryerson research team to accelerate the construction of new bridges and the replacement of deteriorated bridges, a precast barrier wall system was developed and tested to-collapse (Sennah et al., 2008). The proposed barrier wall system is expected to have the following advantages: (i) factory made and inspected barriers are certain to have better appearance and quality than cast-in-place type; (ii) bridge barrier walls can be installed in as less time as one day; (iii) no protruding rebars cages or step/keys interfere with the flat-finished bridge deck surface; (iv) it may be scheduled to be installed any time of the year with no rain or snow but based on the lowest possible temperature for the cement grout to harden; (v) because the barrier is factory made, there is no costly labour-intensive rebar installation in the field; (vi) no expensive barrier forms are needed; (vii) in case of connecting the precast barrier wall with the existing deck slab, drilling down the deck slab can be used; (viii) barrier-to- deck slab joint should not leak water over thru traffic under the bridge in the winter times; and (xi) with use of pretensioning in the connecting rods at barrier-slab joint, no chance of salt and water trapping around the anchor rods or corrosion of bottom plates or nuts is possible.

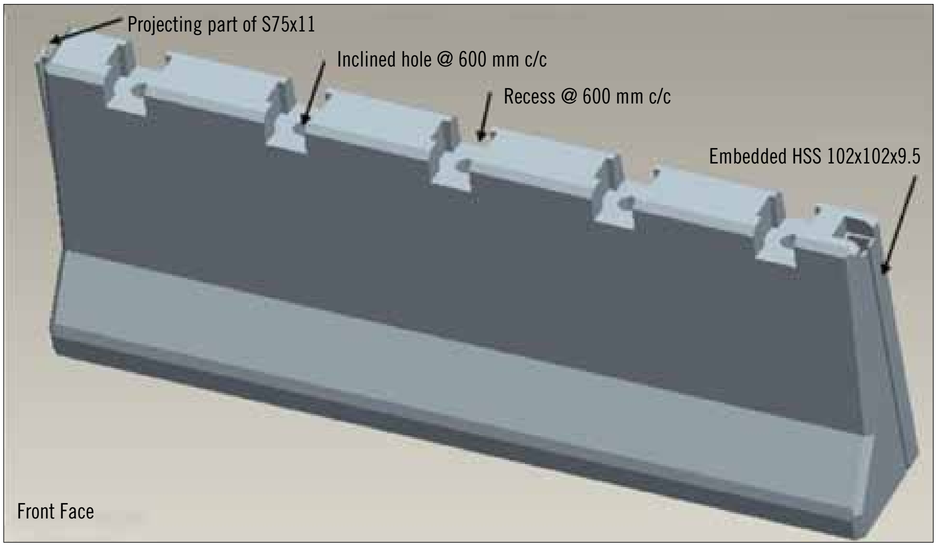

FIGURE 10: View of the Proposed Precast Barrier Wall.

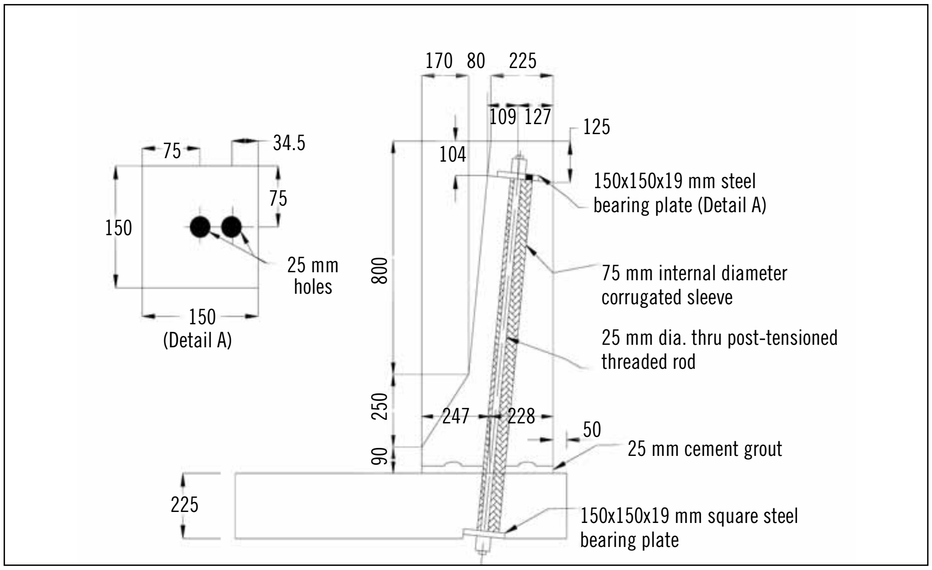

FIGURE 11: Structural Details of the Proposed Precast Barrier Wall Connections.

This investigation resulted in a barrier wall system shown in Figures 10 and 11, in which barrier walls of 3-meter segments would be fabricated in the precast concrete plant and shipped to the bridge site. The proposed barrier wall was intended to meet the criteria for CHBDC performance level 3 (PL-3), representing the majority of bridge barriers in Ontario highways. The geometry of the proposed PL-3 precast barrier wall was similar to the cast-in-place barrier specified in the 2003 Ontario Ministry of Transportation Structural Manual. However, the surface between the barrier wall and the deck slab was flat and horizontal. The depth of the barrier wall measured from top of the wall to top of the concrete deck slab was 1,140 mm, including 1,050 mm net depth over the 90-mm thick asphalt layer. The bottom and top widths of the barrier wall were taken 475 and 225 mm, respectively. A steel corrugated sleeve is to be embedded in the precast concrete slab at an angle equal to the slope of the top inclined portion of the inner face of the barrier. Similar steel corrugated sleeve is to be embedded in concrete deck slab, aligned with that present in the barrier. A 600 mm spacing between sleeves is proposed.

After hardening of the deck slab, an overlay of 25 mm concrete grout material is then introduced over the concrete deck slab edge with a width equal to barrier width. Barrier segments is be laid over the deck slab edges, with centrelines of sleeves aligned so that the 25-mm diameter threaded steel rods can be inserted through. The threaded rods are bolted from the top side of the barrier wall followed by bolting at the bottom side of the deck. A torque force is then applied using mechanical torque to the top nuts to provide initial (pre-tensioned) force in the threaded rod. The intention of the pre-tensioned force is to produce permanent contact pressure (i.e. compressive stresses) at the contact surface between the bottom of the barrier wall and the top of the concrete deck slab. This would assist in preventing water leakage over through traffic under the bridge. To increase shear resistance, the top surface of the concrete deck slab was mechanically scratched in the direction of traffic. To produce similar surface at the bottom side of the precast barrier wall, timber strips can be nailed to the top side of the bottom sheet of timber form to produce the intended corrugated concrete surface. After pre-tensioning the threaded rods to the desired level, concrete grout is to be inserted from a hole in the top steel plate on the side of the top nut (i.e. Detail A in Figure 11) to fill the gap between the threaded rod and the sleeve. Finally, the concrete recesses at the top of the precast barrier wall shown in Figure 10 are grouted.

Figure 10 shows the proposed vertical joint between the precast barrier wall segments. In this case, a HHS 102×102×9.5 tube is embedded on one end of the precast barrier wall segment, with 4 shear studs welded to it to provide anchorage resistance with concrete. On the adjacent precast barrier wall segment, half the size of S 75×11 steel member is embedded in concrete with similar arrangement of shear studs to that of the HSS. While the S-shape steel member projects from the side of the barrier wall. To activate the joint resistance, one barrier wall segment is to be laid over the deck slab. Then, the adjacent barrier wall with the S-shape steel beam is laid over the deck slab vertically in such a way that the projecting portion of the S-shape member slides through a vertical slot in the HSS skin embedded in the other barrier wall edge. The HSS steel tube is then filled with concrete grout to keep the S-shape projecting member in location, thus enhancing the rigidity/continuity of the barrier-to-barrier vertical joint to resist vehicle impact. Few selected barrier configurations were tested to-collapse under equivalent static load

FIGURE 12: Views of the Arrangement of GFRP Reinforcement in the Tested Barrier Before Concrete Casting.

FIGURE 13: General Views of the Barrier Wall Before and After Vehicle Impact.

simulating vehicle impact. Results showed that the developed precast barrier system is "as good as" the cast-in-place barrier system with respect to the static ultimate load carrying capacity.

CRASHWORTHINESS OF GFRP-REINFORCED PL-3 BRIDGE BARRIERS

Corrosion of steel reinforcement due to environmental effects is a major cause of deterioration problems in bridge barriers. Glass fibre reinforced polymers (GFRP), not only addresses this durability problem but also provides exceptionally high tensile strength. A recently developed GFRP bars with end anchorage heads ensure optimal bond between concrete and the bar and eliminate the use of custom made bar bends. A recent design work conducted at Ryerson University on PL-3 bridge barrier proposed the use of 16 mm and 12 mm diameter GFRP bars as vertical reinforcement in the barrier front and back faces, respectively, with 12 mm diameter GFRP bars as horizontal reinforcement in case of PL-3 barrier wall, all at 300 mm spacing. The connection between the deck slab and the barrier wall utilized the GFRP headed end bars for proper anchorage. The design procedure of the barrier wall utilized the available yield-line equations specified in AASHTO-LRFD Specifications for guidance. Two full-scale PL-3 barrier models of 1,200 mm length were erected and tested to-collapse to determine their ultimate load carrying capacities and failure models (Sennah et al., 2010). The first barrier was a control one with reinforcing steel bars, while the second barrier model was reinforced with GFRP bars with headed ends. Based on the data generated from the experimental study, it was concluded that GFRP bars with headed anchorage can be safely used in bridge barrier walls to resist the applied vehicle impact load specified in CHBDC at the barrier wall-deck slab anchorage. However, CHBDC specifies crash testing for the design of the barrier wall itself (i.e. both vertical and horizontal reinforcement).

In November 2010, vehicle crash test was conducted at Texas Transportation Institute in collaboration with Ryerson University and Schoeck Canada Inc. (the GFRP manufacturer). The crash test was performed in accordance with Test Level 5 (TL-5) of MASH, which involves the 36000V tractor trailer (cab-behind-engine model of 36,000 kg gross weight) impacting the barrier at a nominal speed and angle of 80 km/h and 15° degrees, respectively (AASHTO, 2009). This test is intended to evaluate the strength of the barrier in containing and redirecting heavy vehicles. Figure 12 shows schematic diagram of the barrier with GFRP bar arrangement as well as views of the reinforcement before making the timber forms and casting concrete. While Figure 13 shows views of the built 40-m long barrier before and after impact.

The tractor trailer was guided into the test installation using a remote control steering system. The tractor trailer impacted the barrier at 620 mm upstream of the control joint located at 10.8 m from the barrier downstream end. At 0.100 s, the cab of the test vehicle began to redirect, and at 0.203 s, the lower right front corner of the van-trailer contacted near the top of the barrier. At 0.403 s, the cab of the test vehicle was traveling parallel with the barrier at a speed of 79.7 km/h. The van-trailer began traveling parallel with the barrier at 0.667 s, and was traveling at a speed of 76.3 km/h. At 0.695 s, the lower right rear corner of the van-trailer contacted near the top of the barrier, and at 0.748 s, the right rear edge of

FIGURE 14: Sequential Photographs for the Crash Test (frontal views).

FIGURE 15: Sequential Photographs for the Crash Test (side views).

the van-trailer ruptured. As the test vehicle continued along the barrier, it righted itself and rode off the end of the barrier wall. The brakes on the test vehicle were not applied, and the test vehicle subsequently came to rest 35.66 m downstream of the end of the barrier and 2.7 m toward the field side. Sequential photographs for the crash test are presented in Figures 14 and 15 for frontal and side views, respectively.

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas, namely: (i) structural adequacy; (ii) occupant risk; and (iii) vehicle trajectory after collision. Structural adequacy is judged upon the ability of the barrier to contain and redirect the vehicle, or bring the vehicle to a controlled stop in a predictable manner. The vehicle should not penetrate, underride, or override the barrier although lateral deflection of barrier is acceptable. Occupant risk criteria evaluate (i) the potential risk of hazard to occupants in the impacting vehicle and to some extend other traffic, pedestrian, or workers in construction zones, if applicable; (ii) deformation of, or intrusions into, the occupant compartment should not exceed preset limits set forth in MASH; and (iii) whether the vehicle remain upright during and after collision. Post impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles.

Crash test results showed that the barrier contained and redirected the 36000V vehicle. The vehicle did not penetrate, underride or override the parapet. No detached elements, fragments, or other debris from the barrier were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No occupant compartment deformation occurred. The 36000V test vehicle remained upright during and after the collision event. On February 2011, Ryerson research team expects to conduct static load failure tests on the barrier segments to provide research information that will be used further to evaluate the applicability of AASHTO-LRFD yield-line equations, developed for reinforcing steel bars, to the design of GFRP-reinforced barrier. More information about this research program can be found elsewhere (Buth and Menges, 2011; Sennah, 2011). Video clip of the crash test can be watched in the following link: http://www.youtube.com/watch?v=xQDXnISGXhw.

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60 mm lift of asphalt on the bridge and two lifts totalling 100 mm were completed on the approaches. The backfilling and paving operation took approximately 6 hours to complete before all three lanes on the highway could be opened to traffic. Warm weather delayed cooling of the freshly placed hot mix asphalt. The bridge decks had been waterproofed in the days proceeding in the construction staging area. It is believed that the Island Park Drive and the Clyde Avenue Overpasses are the first semi-integral rapid replacements to be completed in North America.

CONCLUSIONS

It is estimated by the Ministry that the reconstruction of the Island Park Drive Overpass using rapid replacement resulted in a net construction savings of $2.4 million when compared to a conventional construction approach. Similar savings were achieved at the Clyde Avenue Overpass. In addition, major construction work on the highway was drastically reduced from a two-year period down to a record-breaking 17 hours and 15 hours respectively. The elimination of traffic queues for 150,000 daily users on Highway 417 had a tremendous impact on the economic activity within the City of Ottawa and is estimated to have resulted in user savings in the millions of dollars and significant social and environmental benefits from the reduction of carbon monoxide emissions. The highly sustainable new crossing is not only designed for a 75 year lifespan achieved through careful material selection (e.g. stainless steel, sacrificial galvanic protection system) but will have greatly reduced maintenance costs with the elimination of expansion joints. ■

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examples related to the topics discussed. They complement the figures (photos and charts) and tables that are featured in the book to aid understanding.

Each chapter includes at the end questions for discussion that stimulate critical thinking and a broad array of references for further reading. The readers will also find useful comprehensive information on the most recent innovations in transit planning and technologies (Appendix 1) and a resources toolbox that lists the web addresses for numerous data sources and organizations involved in ST (Appendix 2). A list of acronyms and abbreviations, a glossary, and an index assist readers in navigating the book.

In conclusion, this is a well-structured, unique book that would be useful to a wide audience, including students, planners, policy and decision-makers, and engaged citizens. I enjoyed reading the book and recommend it to all individuals and organizations that are interested in making our transportation systems more sustainable. ■

Dr. Said M. Easa is Professor and Director of Quality Assurance, Faculty of Engineering, Architecture and Science, Ryerson University, Toronto, Canada. He is Associate Editor of two international journals and editor of the best-selling book *Urban Planning and Development Applications of GIS*, published by the American Society of Civil Engineers (ASCE). He has led a delegation to China focusing on sustainable transportation and land use planning, sponsored by the Canadian Society for Civil Engineering (CSCE). He chaired an ASCE conference on *Transportation, Land Use, and Air Quality: Making the Connection*, held in Portland, Oregon. He also chaired six CSCE transportation conferences that had a sustainability focus. His work, which includes more than 200 refereed journal articles, has received numerous best-paper and lifetime achievement awards from Canadian and U.S. organizations, including the 2010 *Award of Academic Merit* from the Transportation Association of Canada.

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minimise les délais et les fermetures de voies et les inconvénients imposés au public, ce qui épargne du temps et réduit les dépenses des contribuables. En outre, ils offrent aussi des avantages importants au point de vue social et environnemental grâce à la réduction des émissions de monoxyde de carbone.

Les articles retenus pour ce numéro spécial donnent une bonne idée des pratiques les plus récentes en matière de remplacement et de réparation accélérés de ponts. Dans le premier article, Lam et Tharmabala exposent de récentes mises en œuvre, en Ontario, de technologies en matière d'éléments de ponts préfabriqués et de raccordements. Le deuxième article, par Vachon et Islam, expose des applications sur le terrain de remplacement rapide de ponts, en Ontario, avec des transporteurs modulaires auto-propulsés. Ces transporteurs sont des véhicules à plateformes multiples contrôlés par ordinateur qui ont été fortement utilisés pour lever et déplacer du matériel et des structures pour des installations pétrochimiques, côtières, énergétiques et pour des industries du secteur du génie civil. En 2004, une équipe internationale américaine a remarqué ces étonnants appareils qui déplaçaient des ponts en Europe. Cette technologie est maintenant disponible au Canada pour déplacer des éléments de ponts pesant plusieurs milliers de tonnes avec une grande précision allant jusqu'à un pouce (25 mm). Le troisième article, signé par Sennah, Turnbull et Young, traite des plus récentes recherches et applications sur les réparations en accéléré de poutres de ponts endommagées par l'impact de véhicules. L'utilisation de feuilles de CFRP pour réparer les poutres de pont abrège les échéanciers, qui passent de x années à quelques semaines ou même quelques jours, ce qui réduit la congestion routière et les délais, facilite la mobilité et améliore la satisfaction des usagers. Dans le quatrième article, Sennah expose le résumé du programme de recherche effectué par son équipe à l'Université Ryerson sur la construction et le remplacement de ponts en accéléré depuis 2003.

Enfin, au nom du conseil de rédaction de L'ICC et de la division du génie des structures de la SCGC, nous remercions nos collaborateurs qui ont bien voulu rédiger des articles pour ce numéro spécial sur la construction et la réparation de ponts en accéléré. ■

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June 14–17, 2011
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4th International Conference on Durability & Sustainability of Fibre Reinforced Polymer (FRP) Composites for Construction—CDSCC 2011
Québec, QC
July 20–22, 2011
http://www.civil.usherbrooke.ca/cdcc2011

International Venues

Structural Engineers World Congress (SEWC)
Como, Italy
April 4–6, 2011
http://sewc-worldwide.org

International Bridge Conference
Pittsburgh, PA
June 5–8, 2011
http://www.eswp.com/bridge

6th International Structural Engineering and Construction Conference
Zurich, Switzerland
June 21–25, 2011
http://www.isec-society.org/ISEC_06/

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Lugano, Switzerland
August 30–September 1, 2011
http://www.protect2011.supsi.ch/

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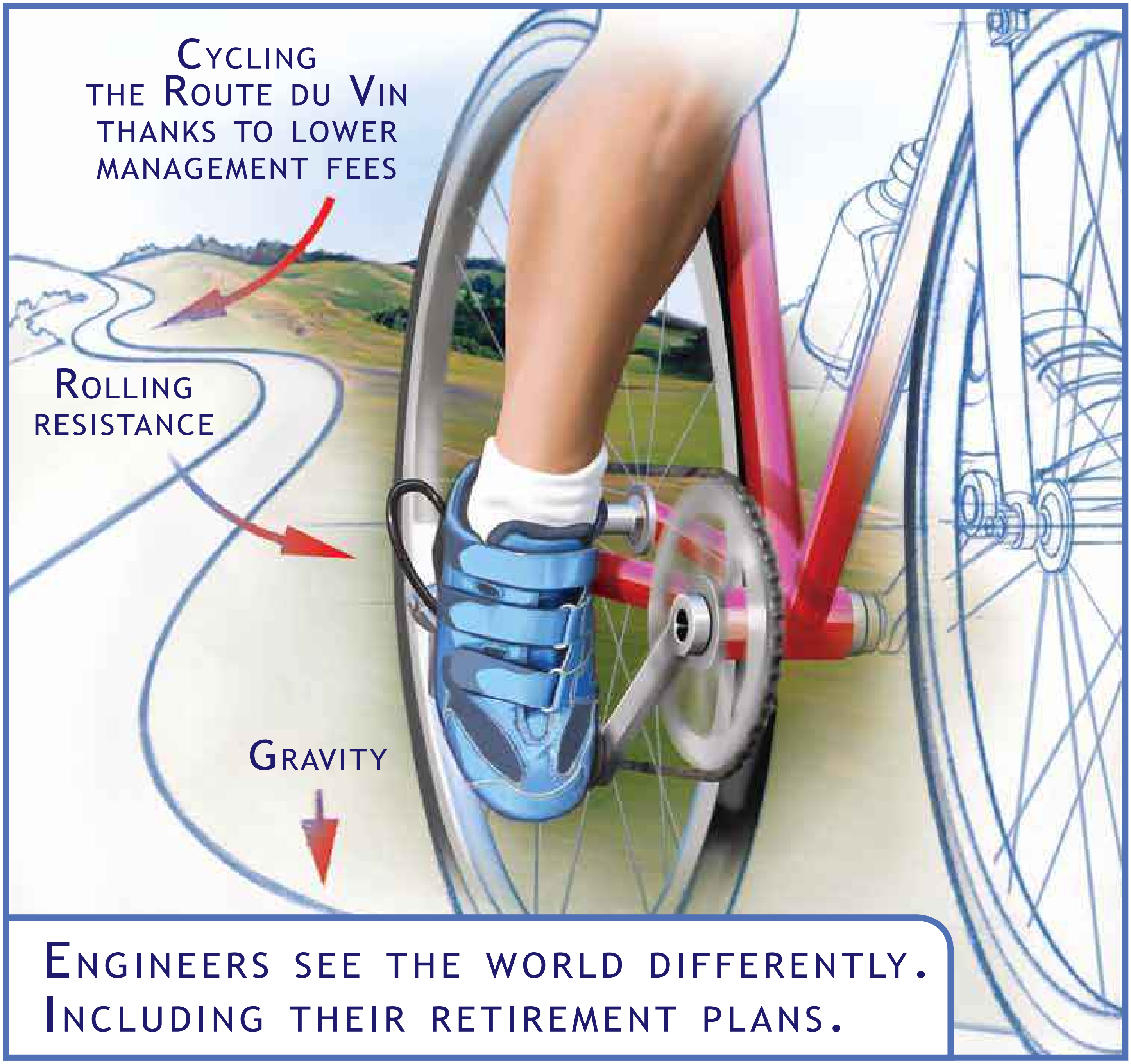
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