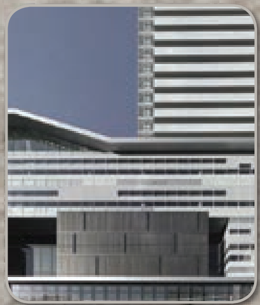
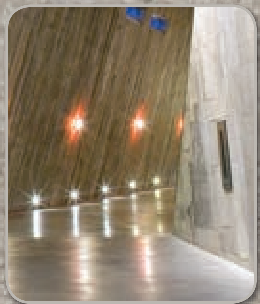
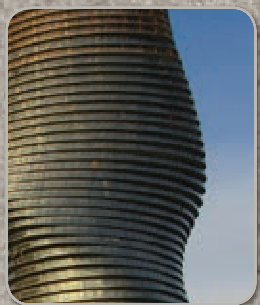
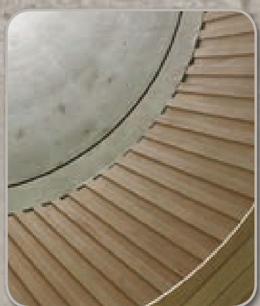





OCCDC

Reinforced Concrete Reference Guide

ONTARIO CAST-IN-PLACE CONCRETE DEVELOPMENT COUNCIL (OCCDC)

VOICE OF THE CONCRETE INDUSTRY

WHO WE ARE

The Ontario Cast-in-Place Concrete Development Council (OCCDC) was established in 1999 by a number of key firms in the Ontario concrete industry. The OCCDC members represent three major stakeholder groups:

- Employer Associations (forming, reinforcing steel, and concrete)
- Organized Labour (carpenters, ironworkers, and labourers)
- Industry Suppliers (formwork materials)

The creation of the OCCDC represents a significant step forward for the Ontario cast-in-place concrete industry in meeting the new challenges faced by all industry stakeholders.

PARTNERSHIPS

The OCCDC works closely with allied groups such as:

- Cement Association of Canada
- Concrete Floor Contractors Association of Ontario
- Concrete Reinforcing Steel Institute
- Ontario General Contractors Association
- University of Toronto

WHAT WE DO

The primary objectives of the OCCDC are:

- **Promotion** of cast-in-place concrete as a superior building system
- **Education** of all industry stakeholders with respect to technical issues and market trends
- **Improved communication**, exchange of information, understanding, cooperation, and cohesion among industry stakeholders

OCCDC general council meetings are held once every three months and are open to both core and associate members. The OCCDC also has created two sub-committees: Marketing & Research and Management, to implement the directives of the general council.

SPECIFIC ACTIVITIES

OCCDC activities include the following:

- Development of technical publications promoting the benefits of cast-in-place concrete as a structural framing system
- Annual production of case histories documenting the effective use of reinforced concrete
- Major supporter of the Ontario Concrete Awards program
- Development of web based preliminary estimating tools for reinforced concrete framing systems
- Providing educational seminars on reinforced concrete at the Concrete/Construct Canada Tradeshow
- Providing educational seminars to Ontario University programs in Architecture and Engineering
- Performing demographic studies for the Ontario concrete construction industry

OCCDC

Ontario Cast-in-Place Concrete Development Council (OCCDC)
365 Brunel Road, Unit 3
Mississauga ON L4Z 1Z5
Phone: 905-507-1122
Fax: 905-890-8122
buildings@occdc.org
www.occdc.org

OCCDC CORE MEMBERS

Aluma Systems is a pioneer and leader in the construction technology industry. Operating in the global marketplace and focused on the success of each customer's project, Aluma systems provide safe, smart & efficient solutions in the fields of industrial maintenance & concrete construction.

www.aluma.com

The **Carpenters District Council of Ontario** is an umbrella organization representing 16 Local Unions in Ontario. The Carpenters Union provides the best trained and most productive skilled carpenters and apprentices performing concrete forming in the Province of Ontario.

www.thecarpentersunion.ca

The **Concrete Forming Association of Ontario (CFAO)** was established in 1971and speaks for the interests of companies working in the institutional, commercial, industrial (ICI) sector of the construction industry. It accounts for the bulk of cast-in-place construction work in the Golden Horseshoe area, the hub of Ontario's economy.

Iron Workers District Council of Ontario is the organization established to oversee the Six Local Unions in the province. The council represents and co-ordinates activities of Ironworkers and Rodworkers throughout the entire province. We supply competent and productive journeymen and apprentices to hundreds of contractors who are involved in concrete and steel construction.

LIUNA Ontario Provincial District Council represents the 12 affiliated local unions throughout the province of Ontario. Building on our over 100 years of experience and dedication to quality, LIUNA have contributed considerably to the establishment of Ontario as the best place in Canada to call home. Together we educate, train and provide the broadest range and best qualified segment of construction craft workers to the forming industry.

www.liunaopdc.org

The **Ontario Formwork Association** is an employers' organization which represents contractors engaged in residential high-rise construction within the province of Ontario. Member contractors are responsible for performing work to approximately 95% of the residential high-rise construction projects in the greater toronto area. At our peak member contractors employ upwards of 4,000 unionized workers.

www.ontarioformworkassociation.com

PERI has considerably added to the continued improvement of construction processes in the field of formwork and scaffolding technology with many pioneering product and safety innovations for better, safer construction.

www.peri.ca

The **Ready Mixed Concrete Association of Ontario** was formed in 1959 to act in the best interest of Ontario's ready mixed concrete producers and the industry in general. It is fully funded by the membership (Active and Associate) and provides a broad range of services designed to benefit its members and the industry in general. With a total membership of about 180 companies, it is recognized as the authoritative voice of the ready mixed concrete industry in Ontario.

www.rmcao.org

Reinforcing Steel Institute of Ontario

RSIO promotes the use of rebar reinforced concrete construction; provides technical information to developers, designers and general contractors and provides information to members.

www.rebar.org

CONSTRUCT™ — CONCEPTUAL SELECTION PROCESS

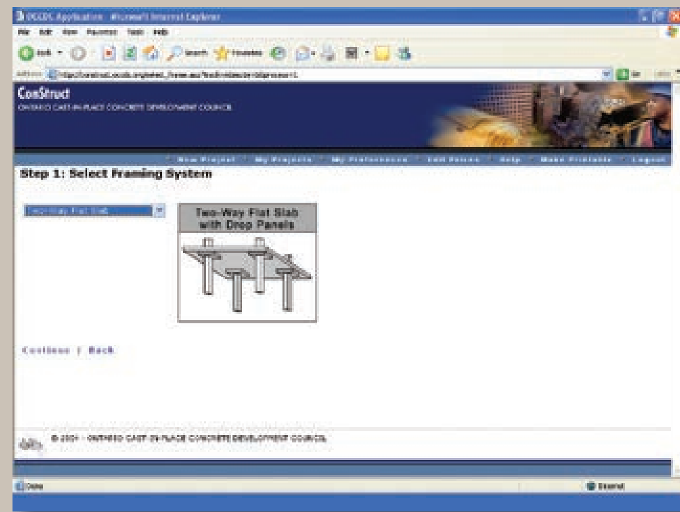
This web-enabled application is an easy-to-use tool that electronically captures all segments of the conceptual selection process that owners and designers must consider when initiating new building projects. Using it can quickly help you become familiar with this proven step-by-step process for the selection of the optimum building structural system.

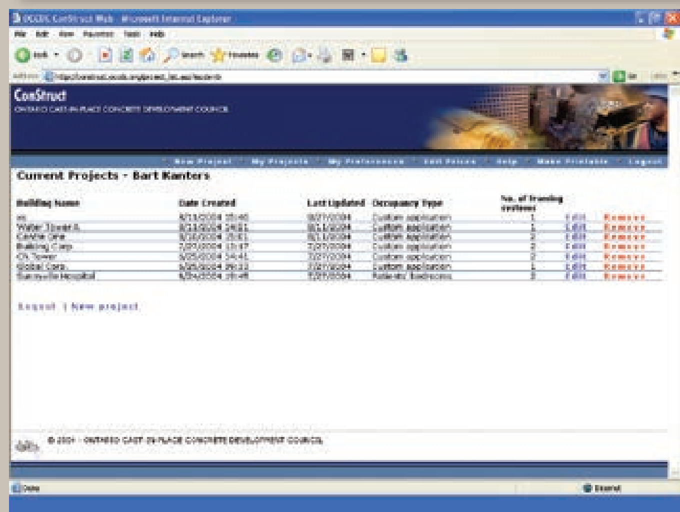
The program was developed for decision makers who want an easy yet complete method of data gathering and evaluation, to ensure that all pertinent criteria is properly considered. This project represents collaboration between the Ontario Cast-In-Place Concrete Development Council (OCCDC) and the Concrete Reinforcing Steel Institute (CRSI), and is applicable to building projects in Canada.

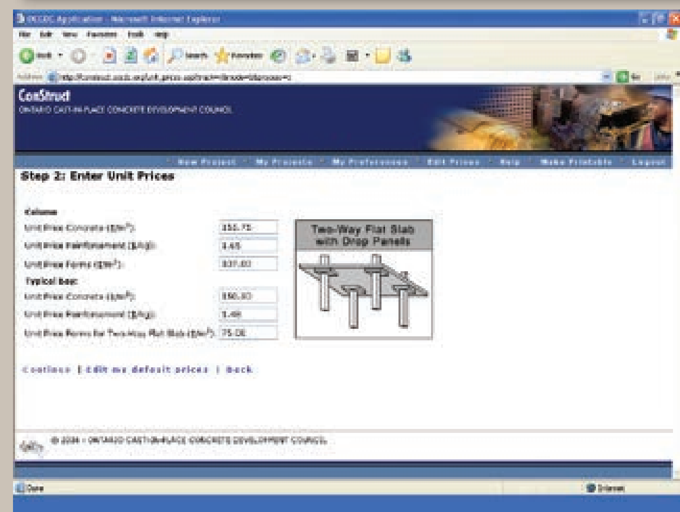
Structural system selection is often based upon perception or past personal experience without a process for evaluating the advantages of new systems or materials. The conceptual selection process provides an orderly way to review pertinent criteria, plus develop quantity and cost factors, which will help you in selecting the most appropriate structural system.

The **ConStruct™** (short for "concrete construction") software program allows you to quickly conduct preliminary estimates of the reinforced concrete structural framing system costs for new buildings during the initial planning stage. Detailed preliminary design calculations are based upon the following six reinforced concrete framing options:

- Two-Way Flat Plate
- Two-Way Flat Slab with Drop Panels
- One-Way Beam and Slab
- One-Way Joist Slab
- One-Way Wide Module Joist Slab
- Two-Way Joist Slab (Waffle)







STRUCTURAL DESIGN INNOVATION AWARD 2010

AeroCentre V

Ontario Concrete Awards

OWNER:
Healthcare of Ontario Pension Plan (HOOPP)

ARCHITECT OF RECORD:
Sweeny Sterling Finlayson & Co. Architects Inc.

ENGINEER OF RECORD:
Stephenson Engineering Ltd.

GENERAL CONTRACTOR:
Vanbots, a division of Carillion Construction Inc.

FORMING CONTRACTOR:
Structform International Limited

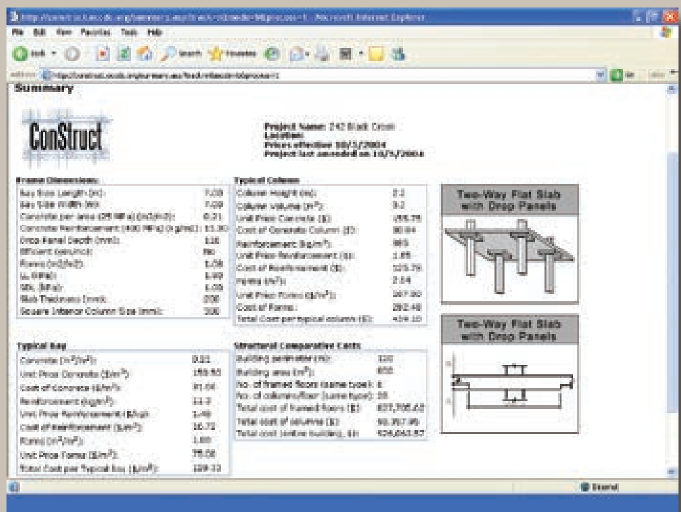
MATERIAL SUPPLIER:
- James Dick Construction Limited
- Armtec Pre-Con Inc.

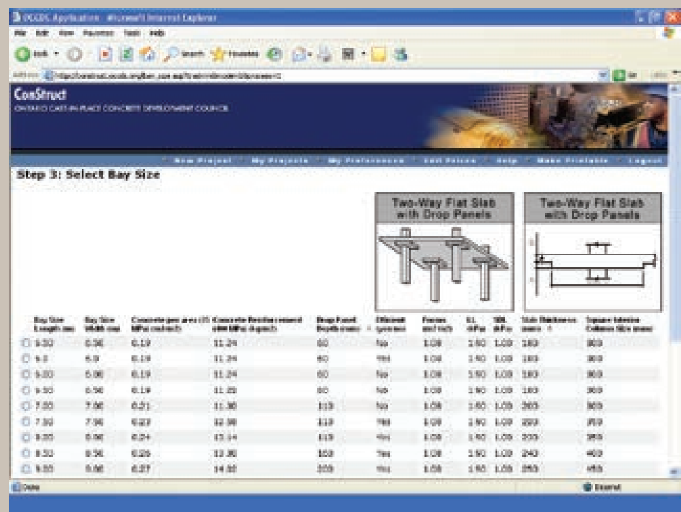
ADDITIONAL PARTICIPANTS:
- Aluma Systems Inc
- BPI Consultants Corp.
- Carpenters Local 27
- Enermodal Engineering
- Harris Rebar
- Ironworkers Local 721
- Manuel Jordao and Associates Limited
- Multiseal Inc.
- Structural Contracting Ltd.
- The Mitchell Partnership Inc.

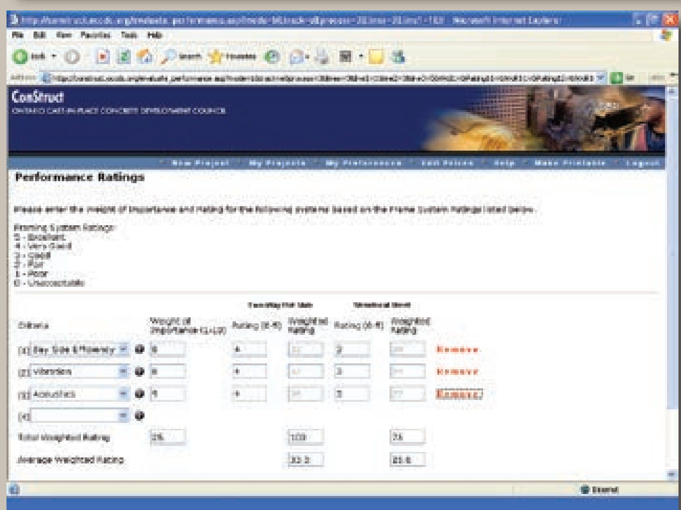
Each framing system has been designed based upon four typical live loads (1.9 kPa, 2.4 kPa, 2.9 kPa & 4.8 kPa) and a superimposed dead load of 1.0 kPa. The program is based upon the requirements of CSA A23.3, the Ontario Building Code and the National Building Code.

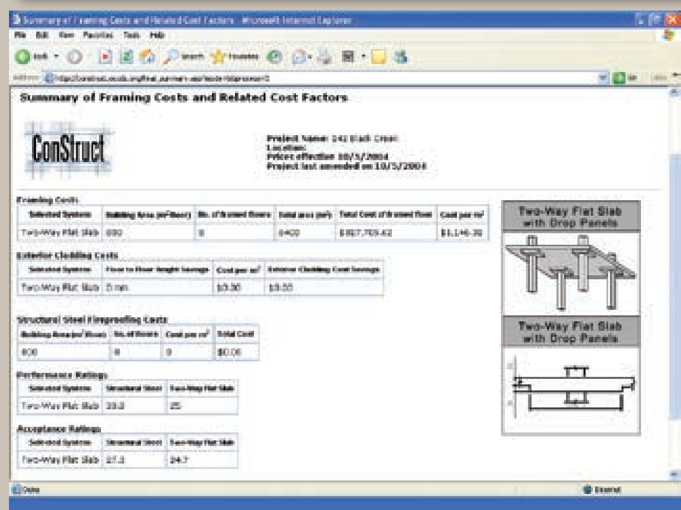
The **ConStruct™** software has been developed as an interactive web application. Individual user projects are stored for up to one year, although users are given a copy of their projects before they are deleted. Some of the advantages and features of this software include:

- Projects are created using your individual account which only you have access to
- There is no software to install or maintain on your computer. The program is entirely web based
- Unit costs for the various construction materials are user specific. While the program starts with default values the user can update the values as appropriate and this information is retained for all future projects
- Project information is saved for future review or editing
- Detailed cost estimates can be printed or electronically pasted into other documents

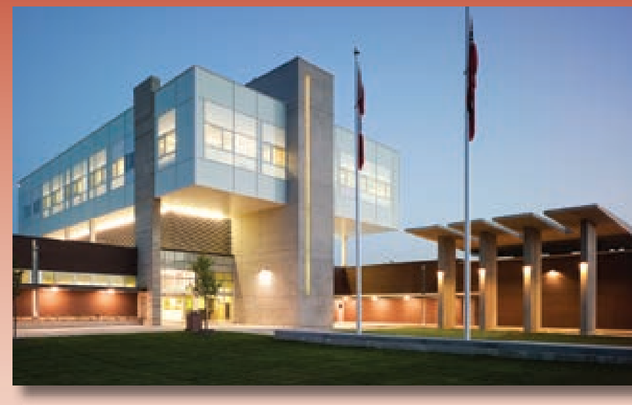








ARCHITECTURAL MERIT AWARD 2010 – CAST-IN-PLACE CONCRETE



Roy McMurtry Youth Centre

OWNER:
Infrastructure Ontario, Ministry of Children and Youth Services

ARCHITECT OF RECORD:
Kleinfeldt Mychajlowycz Architects Inc.

ENGINEER OF RECORD:
Halsall Associates Limited

GENERAL CONTRACTOR:
Bird Construction

MATERIAL SUPPLIER:
Dufferin Concrete, a division of Holcim (Canada) Inc.

ADDITIONAL PARTICIPANTS:
- Carpenters Local 27
- Distrimat Inc.
- Forma-Con Construction
- Frame Architectural and Interior Photography
- Gilbert Steel Limited
- Ironworkers Local 721
- Moon-Matz Ltd.
- National Concrete Accessories
- Quadrangle Architects Limited
- Reckli
- Stantec Inc.

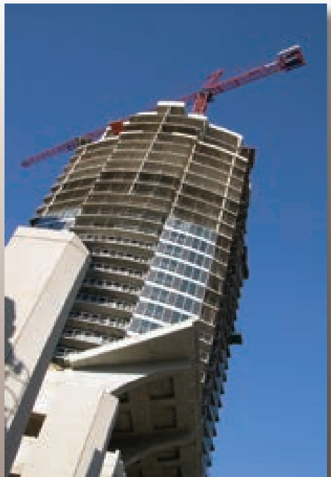
Ontario Concrete Awards

CONCRETE FACT:

The total production of ready mixed concrete in Ontario for 2012 was approximately 10.0 Million cubic metres.

Source: RMCAO

THE ADVANTAGES OF REINFORCED CONCRETE BUILDING FRAMING SYSTEMS



Choosing the best construction material for the framing system of a new building is one of the most important decisions that an owner/developer, architect/engineer or design-build contractor must make.

The construction material selected has a significant impact upon:

- **initial capital costs**
- **speed of construction and early return on investment**
- **the amount of rentable space available**
- **attracting and retaining tenants**
- **yearly energy and maintenance costs**
- **cost of insurance**
- **building aesthetics and public image**
- **resale value**

THE Power of Concrete

REINFORCED CONCRETE IS THE BEST CHOICE FOR THE BUILDING FRAMING SYSTEM BASED UPON THE FOLLOWING ADVANTAGES:

Fast-Track Construction

- **Quicker Start-up Times:** A reinforced concrete framing system does not require extensive preordering of materials and fabrication lead time. Construction can begin on the foundations and lower floors prior to the structural design of the upper floors being finalized.
- **Reduced Total Construction Time:** Reinforced concrete buildings can be constructed at a rate of one floor per week (above the first few floors) and other sub-trades can begin work on completed floors earlier.

Cost Savings

- **Favourable Cash Flow:** Materials and labour are expensed to the project as they are completed, unlike structural steel, where substantial down payments are required months before the material arrives on-site.
- **Standard Floor Layouts:** Repetitive flooring systems which employ flying forms, uniform forming layouts and standard reinforcing steel details lead to significant cost savings.
- **Faster Forming Reuse:** High early strength concrete allows for faster form stripping and reuse.
- **Lower Floor To Floor Heights:** Reinforced concrete framing systems allow for the lowest floor to floor heights, minimizing exterior cladding and vertical servicing costs.
- **Zoning Height Restrictions:** Reinforced concrete framing systems allow for a greater number of floors within a given building height restriction, due to lower floor to floor heights.
- **Thermal Resistance:** The thermal mass of a reinforced concrete structure offers a lower rate of building heat gain or loss resulting in reduced building cooling/heating costs. In addition, lower floor to floor heights result in a reduced interior volume of air that must be heated or cooled by the HVAC system.
- **Fire Resistance:** Reinforced concrete structures are inherently fire resistant and do not require the expensive secondary application of coatings in order to obtain the necessary fire rating values.
- **More Floor Space:** High Performance Concrete (HPC) means smaller column sizes and more rentable floor space.
- **Minimal Maintenance:** Concrete provides a hard, durable wearing surface that resists weathering extremely well.
- **Architectural Finishes:** Reinforced concrete can act both as a structural member and an architectural finish with the use of coloured concrete and special texturing techniques.

Structural Advantages

- **Design Flexibility:** Structural design changes are more easily accomodated in the field with a reinforced concrete framing system due to the fact that the system is constructed on-site rather than months ahead of time at a fabricating plant.
- **Shear Wall Design:** Reinforced concrete shear walls efficiently carry the lateral and gravity loads applied to a building while also acting as interior partitions and sound dampers.
- **Structural Integrity:** Additional reinforcing steel can be used to prevent structural failure under extreme conditions (exterior or interior explosions) at a minimum of cost.
- **Maximum Vibration And Earthquake Resistance:** Reinforced concrete buildings are inherently stiffer than structural steel framing systems thereby eliminating the floor vibration associated with structural steel. Seismic considerations can also be more easily handled with a reinforced concrete framing system through the use of shear walls and reinforcing steel detailing techniques.

- **Sound Isolation:** The high mass of a reinforced concrete structure reduces sound migration from floor to floor and room to room.
- **Underground Parking:** A reinforced concrete framing system easily allows for the creation of underground parking structures, thereby maximizing land use.
- **Minimal Staging Areas:** Concrete pumping techniques allow for high-rise construction in busy downtown centres adjacent to existing structures.

- **Adaptability To Unforeseen Soil Conditions:** Reinforced concrete framing systems can be modified to meet actual site conditions without extensive project delays.

Environmental Considerations

- **Recycled Materials:** Recycled materials are used in the production of reinforcing steel. As well, supplementary cementing materials are waste by-products from other industrial processes that, in the production of ready mixed concrete, improve the performance characteristics of the cast-in-place concrete.
- **Transportation Considerations:** Since reinforced concrete involves a greater use of local materials, the overall environmental costs associated with transportation are reduced.
- **Low Energy Intensity:** While the production of cement is very energy intensive, concrete only contains 9% – 15% cement. Concrete's other major components, aggregates and water, make concrete a very low energy building material.

Local Economy Benefits

- Reinforced concrete framing systems employ the local labour force to construct the building.
- Local Aggregate and Ready Mixed Concrete Producers are used to supply the ready mixed concrete for the building frame.
- A greater portion of the economic benefit of the project is concentrated in the local economy.

Ontario Concrete Awards

SPECIALTY CONCRETE APPLICATIONS 2010

RBC Centre

OWNER:
The Cadillac Fairview Corporation Limited

ARCHITECT OF RECORD:
B+H Architects

ENGINEER OF RECORD:
Halcrow Yolles

GENERAL CONTRACTOR:
PCL Constructors Canada Inc.

MATERIAL SUPPLIER:
St Marys CBM

ADDITIONAL PARTICIPANTS:
- Alliance-Avenue Joint Venture
- Aluma Systems Inc.
- Carpenters Local 27
- Enermodal Engineering
- Gilbert Steel Limited
- Ironworkers Local 721
- Kohn Pedersen Fox Associates
- Peri Formwork Systems Inc.

SIMPLE DESIGN RULES THAT CAN REDUCE PROJECT COSTS

Reinforced concrete is the material of choice for Architects and Engineers due to the fact that it can be sculpted into any shape or form while also acting as the primary structural support for any type of structure. While reinforced concrete is already a very cost effective building material, the designer can realize additional cost savings during the preliminary design stage of the project if they consider the following simple design rules.

FORMWORK CONSIDERATIONS

Select A Single Framing System

The use of multiple framing systems results in higher project costs. Multiple framing systems increase mobilization and formwork costs as well as extending the learning curve for the contractor's work force.

Consider The Use Of Architecturally Exposed Concrete

The extra cost for high quality formwork and concrete placement may be less than other cladding options.

Orient All Framing In One Direction For One-Way Systems

There will be less time-wasting confusion and fewer formwork challenges in the areas where the framing changes direction.

Design For The Use Of "Flying Forms"

Forming costs can be minimized when a repetitive framing system can be used ten or more times on a structure. Repetitive floor & wall layouts will allow for cost savings that can allow for more intricate formwork in high profile areas such as entrance lobbies and common areas.

Space Columns Uniformly From Floor-To-Floor

Uniform column layout results in simpler formwork that can be used repetitively from floor to floor.

Select A Standard Column Size

This can be achieved by varying the amount of reinforcing steel and the concrete strength within the column. This will allow for a single column form and will minimize the number of variations to meet slab or beam forms.

Use The Shallowest Floor Framing System

By minimizing the floor-to-floor height you will be reducing the costs associated with mechanical services, stairs and exterior building cladding. The limiting factor will be deflection considerations.

Make All Beams And Joists The Same Depth

The savings in formwork and shoring costs will exceed any additional costs for concrete and reinforcing steel. This will also provide a uniform ceiling elevation and minimize mechanical service installation difficulties.

Make The Height Of Drop Panels Fit Standard Lumber Dimensions

Standard sizes should be 2.25″, 4.25″, 6.25″ or 8″ (assuming the use of ¾″ plywood).

Use High Early Strength Concrete

This will allow for earlier form stripping and will reduce total construction time.

In 1999, the Ontario Cast-In-Place Concrete Development Council (OCCDC) was formed to aid the owner/developer, architect/engineer and design-build contractor in the decision-making process of choosing the best construction material for the framing system of new structures.

REINFORCING STEEL CONSIDERATIONS

Use The Largest Bar Size That Will Meet The Design Requirements

Large bars reduce the total number of bars that must be placed and minimize installation costs. Avoid the use of 10 M bars whenever possible.

Eliminate Bent Bars Wherever Possible

Bent bars increase fabrication costs and require greater storage area and sorting time on the job site.

Increase Beam Sizes To Avoid Minimum Bar Spacing

Minimum bar spacing results in tight rebar installations and it takes more time to properly place the material. Rebar lapping can also result in bar congestion, which makes proper concrete placement difficult.

Use Lap Splices Where Practical

The cost of additional bar length is usually less than cost of material and labour for mechanical splices.

CONCRETE FACT:

Twice as much concrete is used in construction around the world than the total of all other building materials including wood, steel, plastic and aluminum.

Source: Cement Association of Canada

CONCRETE CONSIDERATIONS

Use High Strength Concrete In Columns

The high strength may reduce the column size or the amount of reinforcing steel required for the column. High strength concrete may also allow for the use of one standard column size throughout the structure.

Do Not Specify Concrete Mix Designs

Allow the Contractor and Concrete Producer to develop site-specific mix designs that meet all of your design requirements and are compatible with the Contractors method of concrete placement. The numbers of mix designs should be limited to two to four to avoid possible ordering confusion.

Consider The Use Of Self Consolidating Concrete (SCC)

Heavily reinforced concrete columns and beams can be very congested with rebar, which prevents the proper placement of the concrete. SCC maximizes concrete flowability without harmful segregation and dramatically reduces honeycombing and rock pockets once the formwork is removed. Visit the RMCAO's website to download a copy of their "Best Practice Guidelines for SCC" and a copy of their SCC cost calculator.

Limit The Coarse Aggregate Size To 20 mm Or Smaller If The Minimum Clear Bar Spacing Is 25 mm

Smaller coarse aggregate sizing may be required in high rebar congestion areas to avoid material segregation and concrete placement difficulties (honeycombing, rock pockets, etc).

Require A Concrete Quality Plan

This document will indicate how the contractor and their sub-contractors and material suppliers will ensure and verify that the final reinforced concrete product meets all of the specification requirements.

OCCDC promotes the benefits of reinforced concrete as the construction material of choice based upon the following advantages:

Fast-Track Construction

Cast-in-place concrete offers quicker start-ups and reduced total construction time.

Cost Savings

Lower floor-to-floor heights, high fire resistance and minimal maintenance costs are achieved with cast-in-place systems.

Structural Advantages

Design flexibility, structural integrity, sound and vibration isolation, as well as the ability to include underground parking are some of the advantages provided by concrete structures.

Environmental Considerations

The use of local aggregates and recycled materials (slag & fly ash) in concrete, make it a "green" product that is requested by environmentally responsible owners

Local Economy Benefits

Cast-in-place concrete framing systems utilize the local work force and materials, as well as maximizing the economic benefit to the community

OCCDC

REINFORCING STEEL INSTITUTE OF ONTARIO

OUR OBJECTIVES

One of the objectives of the Members of the Reinforcing Steel Institute of Ontario is the development of and adherence to industry standard practices that: ensure the safety of both the public and our workers and provide quality construction at competitive costs to the buyer.

The RSIO is a nonprofit organization whose members are companies that are fabricators, steel mills and suppliers to the reinforcing steel industry. The members collectively as the institute assist the design and the construction professionals in the best uses and applications for reinforced concrete structures.

As the Institute promotes these standards practices, it contributes greatly to advancement and development of reinforced concrete structures. The RSIO website hosts the sales of the RSIC Manual of standard practice, it is highly regarded in the industry, providing valuable information on all aspects of the reinforcing steel industry. Contact the RSIO for info.

CHECK OUT

www.rebar.org

REBAR
Abbreviated term for Reinforcing Steel Bar.

Reinforcing Steel Institute of Ontario
PO Box 40620
RPO Six Point Plaza
Toronto, Ontario, M9B 6K8
Phone: 416-239-RSIO (7746)
Fax: 416-239-7745

REINFORCING STEEL BAR
Deformed steel bars used in the reinforcing of concrete.

Order your manual today and learn about

THE ELEMENTS OF REINFORCING STEEL

Architectural/Engineering Information (see chapter 1)

Material Standards and Specifications (see chapter 2)

Standard Quotation Components (see chapter 3)

Standard Practices for Estimating and Detailing (see chapter 4, 5)

Fabrication Standards (see chapter 6)

Standards for Placing and Bar Supports (see chapter 7, 8)

Reinforcing Steel in Corrosive Environments (see chapter 9)

Requirements for Splicing (see chapter 10)

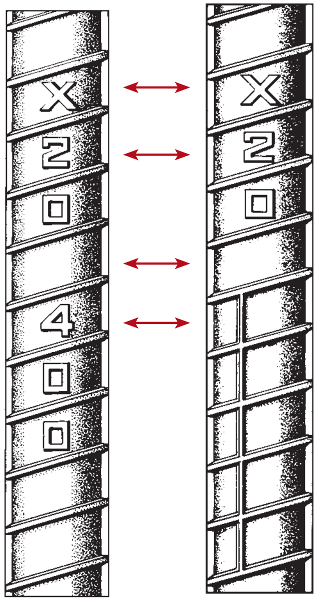
Welded Wire Fabric Standards (see chapter 11)

Standards for Post-Tensioning (see chapter 12)

IDENTIFICATION REQUIREMENTS

Deformed Concrete Reinforcing Bar comply with
CSA Standard G30.18-09

SEQUENCE



MILL SYMBOL – ON ALL GRADES

BAR SIZE – ON ALL GRADES

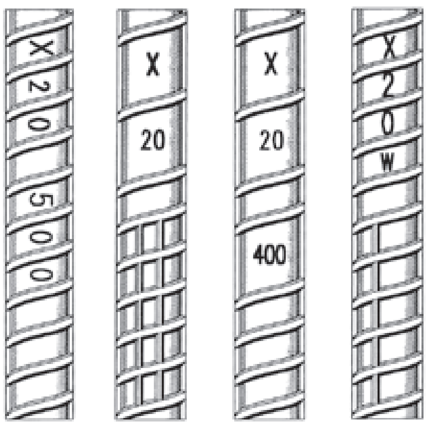
BLANK SPACE – IF GRADE SYMBOL IS IN NUMBERS

GRADE SYMBOL – OPTIONS ALLOWED

Grade 400R	Either the number 400 or one offset line through at least 5 spaces
Grade 500R	Either the number 500 or two offset lines through at least 5 spaces
Grade 400W & 500W	The letter W between the blank space and the grade symbol or in the blank space

NOTE: The letter R is not rolled onto the bar.

POSSIBLE VARIATIONS



To achieve clarity of symbols on all sizes and to accommodate a variety of roll marking techniques it has been trade practice for mills to modify symbol size or orientation while still observing the prescribed sequence.

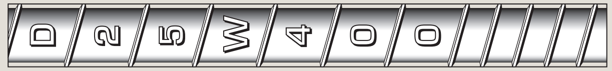
NOTE: Identification markings occur at intervals of 1 to 1.5 metres along the bars.

SHEAR REINFORCEMENT

Reinforcement designed to resist shearing forces; usually consisting of stirrups bent and located as required.

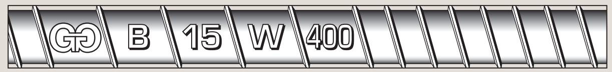
TYPICAL IDENTIFICATION PATTERNS OF PRODUCERS SUPPLYING THE CANADIAN MARKET

AltaSteel Ltd.
An Arrium Company



ArcelorMittal LCNA
Longueuil Mill

ArcelorMittal LCNA
Contrecoeur West



Gerdau
Beaumont Mill

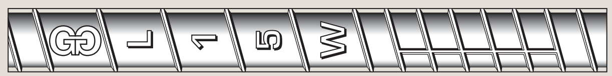
Gerdau
Cambridge Mill

Gerdau
Manitoba Mill

Gerdau
Sayreville Mill

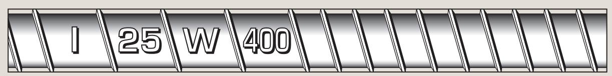
Gerdau
St Paul Mill

Gerdau
Rancho Cucamonga Mill

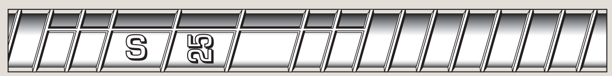


Gerdau
Whitby Mill

North American Stainless



Nucor Auburn NY



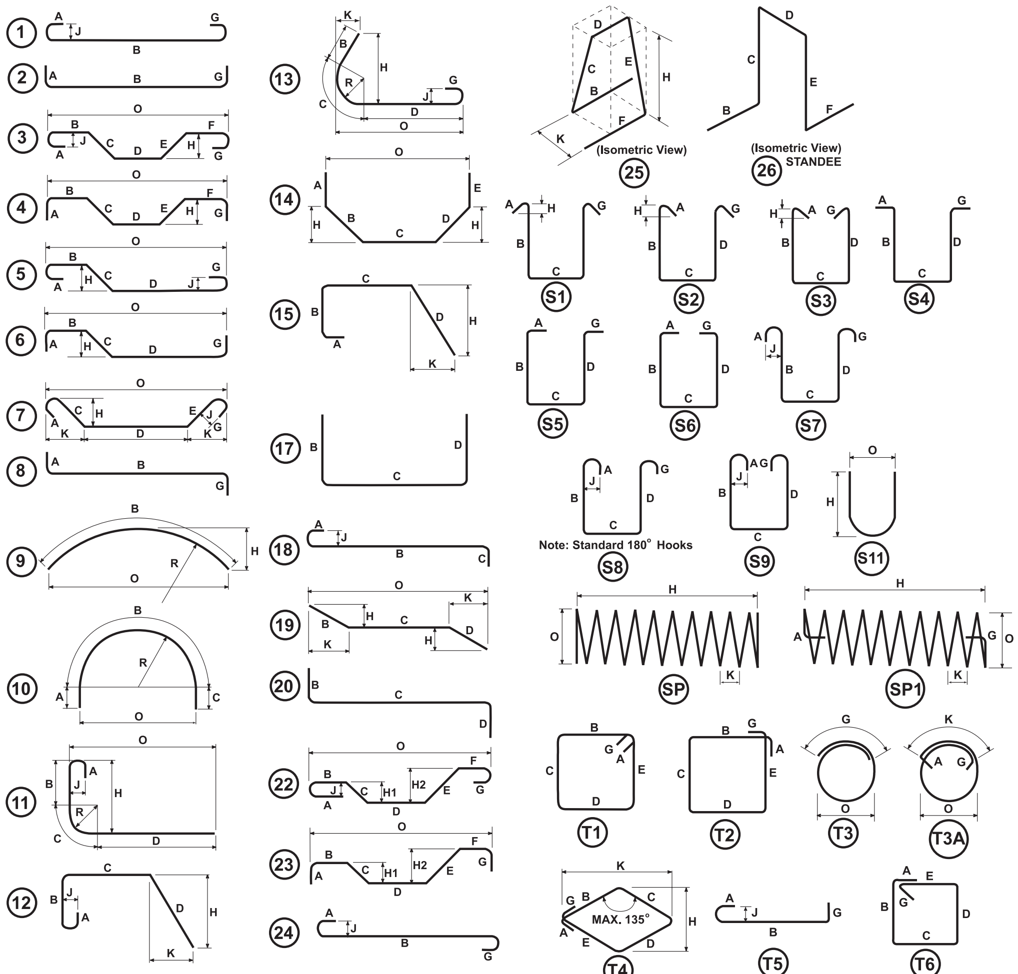
Nucor Steel Seattle Inc.

Valbruna Canada Inc.

RSIC identifies those producing mills who are industry members of the RSIC and who participate financially and as technical advisors in the activities of the Institute.

REINFORCING STEEL INSTITUTE OF ONTARIO

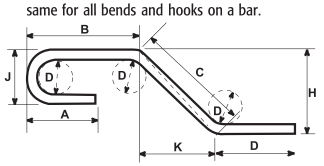
TYPICAL BAR BENDS



NOTES:
1. All dimensions are out-to-out of a bar except "A" and "G" on standard 180 and 135 hooks.
2. "J" dimensions on 180 hooks to be shown only where necessary to restrict hook size, otherwise standard hooks are to be used.
3. On Truss bars "J" will be kept equal to or less than "H". Where "J" can exceed "H" it should be shown.
4. On stirrups "H" dimension should be shown only where necessary to fit within concrete.
5. Critical dimensions are to be identified where bars are to be bent more accurately than standard bending tolerance.
6. On type T3 "G" dimension is equal to Class B splice.
7. Figures shown in circles show types.
8. All bar bends other than the types shown above must be designated as type "X".

RSIC IAAC

Unless otherwise noted diameter "D" is the same for all bends and hooks on a bar.

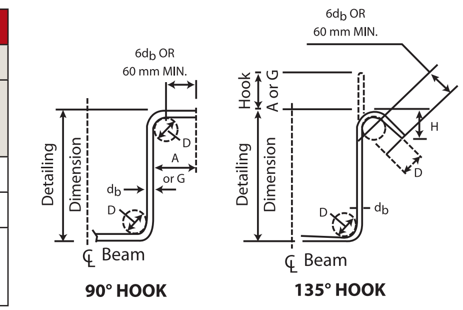


ENLARGED VIEW SHOWING BAR BENDING DETAILS

HOOK DIMENSIONS

STIRRUP AND TIE HOOK DIMENSIONS

BAR SIZE	BAR DIAM. d_b(mm)	PIN DIAM. D(mm)	90° HOOK AorG (mm)	135° HOOK AorG (mm)	135° HOOK H(approx.) (mm)
10M	11.3	45	100	100	70
15M	16.0	65	140	140	100
20M AND LARGER	SAME AS 180° HOOK				



90° HOOK

135° HOOK

EMBEDMENT LENGTH

The length of embedded reinforcement provided beyond a critical section.

BAR LIST

List of bars indicating such things as: mark, quantity, size length and bending details.

REINFORCING STEEL BARS

BAR DESIGNATION NUMBER (BAR SIZE)	MASS kg/m	NOMINAL DIMENSIONS DIAMETER mm	CROSS SECTIONAL AREA mm2	PERIMETER mm
10M	0.785	11.3	100	35.5
15M	1.570	16.0	200	50.1
20M	2.355	19.5	300	61.3
25M	3.925	25.2	500	79.2
30M	5.495	29.9	700	93.9
35M	7.850	35.7	1000	112.2
45M	11.775	43.7	1500	137.3
55M	19.625	56.4	2500	177.2

The nominal diameter, d_b, of metric reinforcing may be taken as the bar designation number.

HOOK DIMENSIONS

STANDARD HOOK DIMENSIONS FOR BLACK REINFORCING

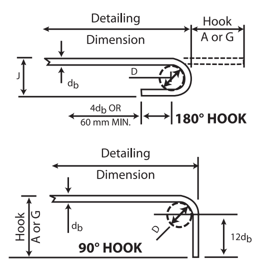
BAR SIZE	BAR DIAM d_b(mm)	400R or 500R D	400R or 500R 90° HOOK Aor G* (mm)	400R or 500R 180° HOOK Aor G* (mm)	400R or 500R J (mm)	400W or 500W D	400W or 500W 90° HOOK Aor G* (mm)	400W or 500W 180° HOOK Aor G* (mm)	400W or 500W J (mm)
10M	11.3	70	180	140	90	60	180	130	80
15M	16.0	100	260	180	130	90	250	170	120
20M	19.5	120	310	220	160	100	300	200	140
25M	25.2	150	400	280	200	150	400	280	200
30M	29.9	250	510	400	310	200	490	350	260
35M	35.7	300	610	480	370	250	590	430	320
45M	43.7	450	790	680	540	400	770	620	490
55M	56.4	600	1030	900	710	550	1010	830	660

\# The dimensions provided use the minimum bend diameters (D) permitted in (CSA A23.1-09 CL.6.6.2.3 and Table 16).
ñ Standard hooks are defined in (CSA A23.1-09 CL.6.6.2.2).
* Add the additional hook dimension G to the detailing dimension to estimate the total bar length.
† To achieve this "J" dimension the pin diameter is less than the standard pin diameter.

STANDARD PIN DIAMETER (D) FOR 90° AND 180° HOOKS

Grade 400 Uncoated Bars
$D = 6d_b$ for 10M to 25M
$D = 8d_b$ for 30M to 35M
$D = 10d_b$ for 45M to 55M

Epoxy Coated Bars
$D = 8d_b$ for 10M to 30M
$D = 10d_b$ for 35M to 55M



180° HOOK

90° HOOK

PLACING

Placing Reinforcing Bars

Reinforcing bars should be accurately placed in the positions shown on the placing drawings, adequately tied and supported before concrete is placed, and secured against displacement within the tolerances recommended in RSIC Manual of Standard Practice, Chapter 7. Welding of crossing bars (tack welding) should not be permitted for assembly of reinforcement unless authorized by the Architect/Engineer.

Placing Drawings

As the term implies, "placing drawings" are used by Ironworkers at the job-site to place (install) the reinforcing steel within the formwork. In preparing the placing drawings for a specific structure, the Detailer determines the quantity of reinforcing bars, bar lengths, bend types, and bar positioning from the information and instructions provided on the project drawings and in the project specifications. Placing drawings are not design documents since they only convey the Architect/Engineer's intent. Thus, project specifications should not require that a Licensed Professional Engineer prepare or check and seal the placing drawings. The latest edition of RSIC "Manual of Standard Practice" is recommended for details. For more information visit our website at www.rebar.org.

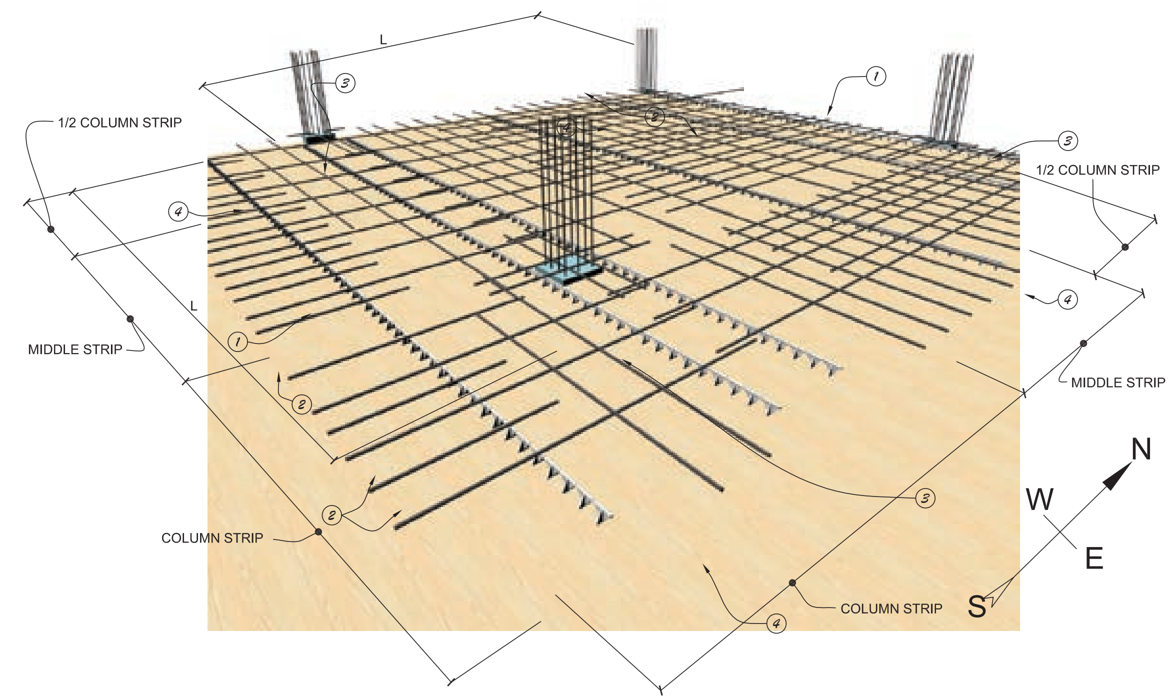
BAR SUPPORTS

The use of bar supports should follow the industry practices presented in Chapter 8 of RSIC Manual of Standard Practice. Placing reinforcement on layers of fresh concrete as the work progresses and adjusting the bars during the placing of concrete should not be permitted. Bar supports may be made of steel wire, precast concrete, or plastic.

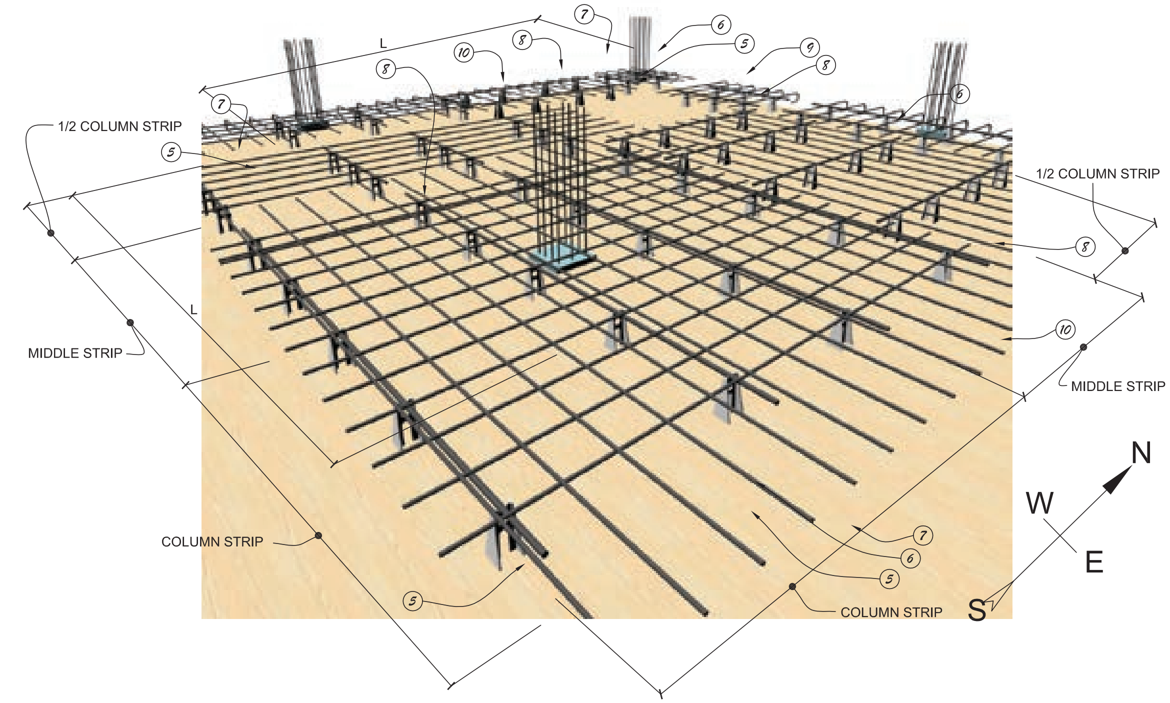
FABRICATION OF REINFORCING BAR

Fabrication consists of the cutting, identification of bars, bundling, bending and loading for transport, reinforcing steel to a specified bar list. ***It is recommended that all reinforcing bars be shop fabricated, since fabrication operations can be performed with greater accuracy in the fabricating shop.*** All bar bending should conform to the typical bar bends illustrated in RSIC *Manual of Standard Practice*. Dimensions of a bent reinforcing bar are the overall measurements and, unless otherwise specified on the project drawings or in the project specification, bent reinforcing bars are furnished to standard tolerances. The latest edition of RSIC Manual of Standard Practice is recommended for more details.

SEQUENCE OF PLACING BOTTOM BAR SUPPORTS AND BARS



SEQUENCE OF PLACING TOP BAR SUPPORTS AND BARS



WELDED WIRE FABRIC

Welded Wire Fabric (WWF) is a prefabricated reinforcement consisting of parallel series of high strength, cold-drawn or cold-rolled wire welded together in square or rectangular grids. Each wire intersection is electrically resistance-welded by a continuous automatic welder. Pressure and heat fuse the intersecting wires into a homogeneous section and fix all wires in their proper position. Plain wire, deformed wire or a combination of both may be used in WWF.

Welded smooth wire reinforcement in standard sheets or rolls, referred to as "construction mesh", is commonly specified as temperature and shrinkage reinforcement in slabs. It bonds to concrete by the positive mechanical anchorage at each welded wire intersection. Standard styles are listed in Table 11.2 and 11.3 of the manual.

STANDARD METRIC CONSTRUCTION FABRIC

METRIC DESIGNATION	IMPERIAL EQUIVALENT	STEEL AREA SQ.MM/LIN. M	WEIGHT KG /SQ. M	STANDARD SIZE ROLLS, SHEETS EASTERN CANADA	STANDARD SIZE ROLLS, SHEETS WESTERN CANADA
152x152 MW9.1 x MW9.1	6x6 10x10	59.9	1.02	ROLL* 8x20	ROLL**, 7-6 x10, 7-6 x 20
152x152 MW11.1 x MW11.1	6x6 9x9	74.3	1.22	ROLL* 4x8 8x12 8x20	
152x152 MW13.3 x MW13.3	6x6 8x8	88.7	1.46	8x20	ROLL*+ , 7-6 x 20
152x152 MW18.7 x MW18.7	6x6 6x6 ***	124.5	2.05	ROLL* 4x8 8x12 8x16 8x20	ROLL*+ , 7-6 x 20
152x152 MW25.7 x MW25.7	6x6 4x4 ***	171.5	2.83	8x12 8x20	7-6 x 20
152x152 MW34.9 x MW34.9	6x6 2x2	232.8	3.81	8x12 8x20	7-6 x 20
152x152 MW47.6 x MW47.6	6x6 0x0	317.3	5.22	8x12 8x20	7-6 x 20
102x102 MW18.7 x MW18.7	4x4 6x6 ***	186.8	3.02	8x12 8x20	7 x 20
102x102 MW25.7 x MW25.7	4x4 4x4 ***	257.2	4.14	8x12 8x20	7 x 20
203x203 MD51.6 x MD51.6	8x8 D8XD8	257.2	4.14	8x14	
305x305 MW22.2 x MW22.2 Step through	12x12 XW3.4xW3.4	73.0	1.22	8x20	8x20
305x305 MW37.4 x MW37.4 Step through	12x12 W5.8xW5.8	123.0	2.05	8x20	8x20
305x305 MW51.5 x MW51.6 Step through	12x12 W8xW8	170.0	2.83	8x20	8x20
102x152 MW43.9 x MW39.4 Road Mesh	4x6 W6.1xW6.1	430.1 / 259.2	5.9	8x14	

* ROLLS = 6x200 6x100
** ROLL 6x6 10x10 MESH AVAILABLE 7--6 x 200, 5 x 200, 5 x 100, 4 x 200
*** Also Available in Galvanized sheet 8x20
*+ ROLL 7-6 x 200

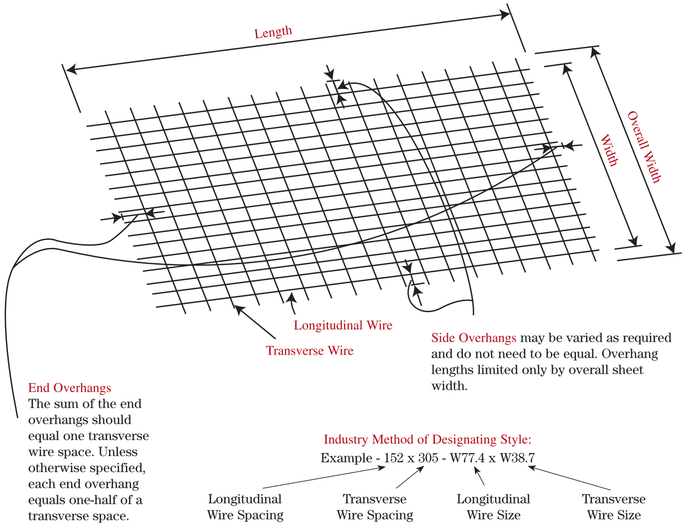
YIELD STRENGTH

The stress at which the reinforcing steel exhibits plastic, rather than elastic behavior.

SPACING FOR SUPPORT ACCESSORIES

Type of WWF	DIAMETER/SIZE	SPACING
Heavy	MW 58.1 and larger	1.2 to 2.0m
Medium	MW 32.3 to 51.6	0.9 to 1.2m
Light	MW 25.8 or less	0.8m or less

NOMENCLATURE



MANUFACTURING SPECIFICATIONS COVERING WWF

U.S. Specifications	Title
ASTM A 82	Cold Drawn Steel Wire for Concrete Reinforcement
ASTM A 185	Welded Steel Fabric for Concrete Reinforcement
ASTM A 496	Deformed Steel Wire for Concrete Reinforcement
ASTM A 497	Welded Deformed Steel Wire Fabric for Concrete Reinforcement

MINIMUM MECHANICAL PROPERTIES FOR WWF

Type of WWF	Minimum Tensile Strength	Minimum Yield Strength Fy	Minimum Weld Shear Strength
Smooth Wire Fabric	515 Mpa	450 Mpa	240 Mpa
Deformed Structural Wire Fabric	550 Mpa	485 Mpa	240 Mpa (ASTM) 140 Mpa (CSA)

SPLICING

Limitations on the length of reinforcing steel bars due to manufacturing, fabrication, transportation and constructability restraints make it impossible to place continuous bars in one piece throughout the structure. Such conditions may necessitate splicing of reinforcing bars. Other conditions may require the use of splices such as, but not limited to rehabilitation work, future expansion and connecting to existing structures. Properly designed splices are key elements in design.

The recommendations and examples in the RSIC Manual of Standard Practice concerning the type of splice, method of splicing, welding processes and splicing devices are merely illustrative. Proper engineering must be followed to achieve the specific design requirements. Some proprietary splicing devices are shown in this chapter for information purposes only.

Splices are designed for Tension or Compression. There are three methods of splicing:

- Lapped;
- Mechanical;
- Welded.

Each method can be used for either compression splices or tension splices.

MILLIMETRES OF LAP RELATED TO NUMBER OF BAR DIAMETERS

BAR SIZE	BAR DIAM	NUMBER OF BAR DIAMETERS (Using Bar Size)							
		10	12	20	24	30	36	48	54
10M	11.3	100	120	200	240	300	360	480	540
15M	16.0	150	180	300	360	450	540	720	810
20M	19.5	200	240	400	480	600	720	960	1080
25M	25.2	250	300	500	600	750	900	1200	1350
30M	29.9	300	360	600	720	900	1080	1440	1620
35M	35.7	350	420	700	840	1050	1260	1680	1890
45M	43.7	LAP NOT PERMITTED							
55M	56.4	LAP NOT PERMITTED							

TEMPERATURE BARS

Bars distributed throughout the concrete to minimize cracks due to temperature changes.

REINFORCING STEEL IN CORROSIVE ENVIRONMENTS

The RSIC Manual of Standard Practice discusses the materials available for corrosive environments. Specifically covered are Epoxy Coated Reinforcing Steel, Stainless Steel and Hot Dipped Galvanized Reinforcing Steel. These various types of materials are used to deter concrete spalling. Spalling is a premature deterioration of reinforced concrete due to corrosion of reinforcing steel. This corrosion takes place when solutions containing materials such as; salt, potash or sulphur, penetrate the surface of concrete structures and attack the reinforcing steel.

Application

Many types of concrete structures are subjected to a corrosive environment where Epoxy Coated Reinforcing Steel, Stainless Steel or Hot Dipped Galvanized Reinforcing Steel would be beneficial. Primary applications include: bridges, parking garages, seawater structures, water and sewage treatment facilities, mining projects, chemical plants, and processing plants where chemicals are used.

DETAILING

The detailing service rendered by the Fabricator never replaces the function of the Architect and the Structural Engineer. The purpose of this detailing service is to facilitate the efficient fabrication and installation of the reinforcing steel. Effective detailing service can be performed only if all dimensions and related information are available. Lacking this, the Detailer must make time-consuming and possible job-delaying inquiries. Detailing without clear instructions from the Engineer invariably involves additional work for all concerned.

Responsibility

No responsibility shall be assumed by the Fabricator for the structural design or the accuracy of the dimensions on the drawings supplied by others. The Fabricator shall not be held responsible for the coordination or accuracy of information shown on drawings or bar lists furnished by others.

Approval Of Reinforcing Steel Placing Drawings

The Engineer – unequivocally the final decision maker – shall either approve, or approve with corrections, or disapprove proposed details. Only the structural Engineer has performed the analysis for all loading effects and knows the effective area of steel required at all locations, and thus must provide interpretations of Building Code requirements.

Standard Practice in the industry is such that the reinforcing steel Fabricator will not provide a professional Engineer's stamp on the placing drawings as prepared by the reinforcing steel Detailer.

RSIC Detailer Certification Program

In order to standardize the practice of detailing, the RSIC developed a Detailer certification program.

The RSIC standards for certification of a reinforcing steel Detailer ensure a minimum of a 2 year apprenticeship period. Placing drawings are then submitted to the RSIC certification committee for review, upon approval certification is granted.

TIE WIRE

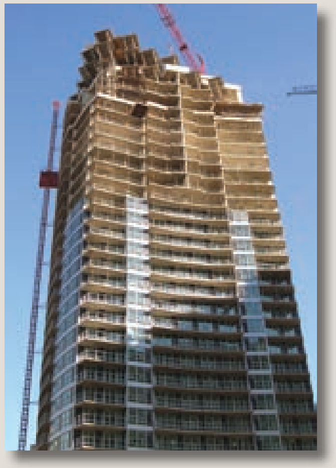
Annealed wire (16 gauge) used to secure intersections of reinforcing bars for the purpose of holding them in place.

SURFACE CONDITION OF REINFORCING BAR

At the time of concrete placement, all reinforcing bars should be free of mud, oil, or other deleterious materials. Reinforcing bars with rust, mill scale, or a combination of both should be considered as satisfactory, provided the minimum dimensions, weight and height of deformations of a hand-wire-brushed test specimen are not less than the applicable ASTM specification requirements. RSIC publishes detailed guidance on this subject available on RSIC's ***Manual of Standard Practice***.

ONTARIO FORMWORK ASSOCIATION

WHO WE ARE



The Ontario Formwork Association is an organization of High Rise Formwork Contractors. The Association was formed in 1968 to provide a forum for members to discuss subjects of common interest to the formwork sector of the construction industry in Ontario. Since that time the Association has grown to reflect the needs of its membership in a business environment, which has been and continues to be affected by an expanding economy, an ever increasing regulatory environment and significant changes in technology.

Today the Association represents member firms with a work force of approximately 4,000 unionized workers. Our active participation in industry matters provides our membership with the benefits of industry-wide knowledge and experience. Member firms are responsible for approximately 95% of the residential high-rise construction within the province of Ontario.

"We have a genuine and deep rooted commitment to quality."

WHAT WE DO

The Ontario Formwork Association is able to put at your fingertips an enormous body of proven knowledge and expertise both in terms of management and in the field. Our members are at the leading edge of new technology and management techniques. Few construction associations, anywhere in the world can offer as much experience, both local and international. We have a genuine and deep rooted commitment to quality and take pride in the fact that our construction and management expertise can guarantee that a building is carried out quickly and efficiently at the best possible cost.

Formwork enjoys considerable advantages over other construction methods including structural steel in terms of durability, safety, speed, sound insulation and cost effectiveness, to name but a few. It has a history for satisfying people's desire for comfort and security in aesthetically pleasing surroundings. Add these advantages to those offered by our Association and the solution to future construction needs becomes clear. The future is formwork. The future is with the experts.

"The future is formwork. The future is with the experts."

WHERE WE WORK

Most of our projects are situated in the province of Ontario, although we work in other Canadian provinces, the United States, Mexico, the Caribbean, Western Europe and Middle Eastern Countries. Ontario is Canada's largest province and construction its largest industry, with an excess of $100 billion a year focused on the building industry. Building and construction employs 6.5% of the Ontario workforce.

The Ontario Formwork Association has been equally innovative in all of these areas and our member companies are generally regarded as leaders in the field – both at home and abroad.

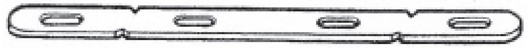
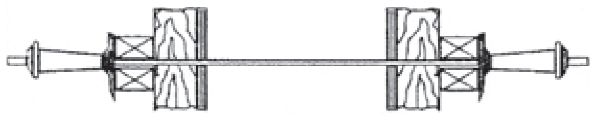
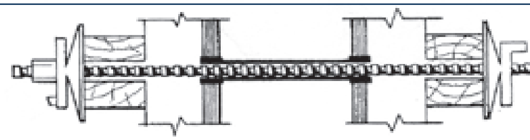
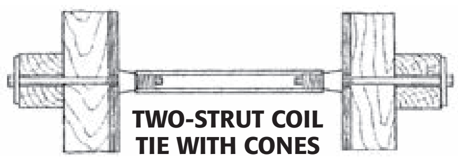
"The Ontario Forming Industry is a world leader in quality, innovation and efficiency."

CONCRETE FACT:

Concrete is second only to water as the most consumed substance in the world

Source: Globe & Mail

FORMWORK FOR CONCRETE

ONE-PIECE TIES	 FLAT TIE	Used to secure and space modular panel forms. Available in several configurations. Notched for breakback. **SAFE LOADS 1500, 2250, and 3000 lb**
	 LOOP TIE	Secures and spaces prefabricated modular forms. Notched for a 1" breakback. Crimp is anti-turn feature. **SAFE LOADS: 2250 and 3000 lb**
	 SNAP TIE WITH SPREADER WASHERS	Used for job-built forms, lighter construction. May have cone spreader and waterseal washer. Notched for a 1" breakback. **SAFE LOADS: 2250 and 3350 lb**
	 FIBERGLASS TIE	Long lengths supplied for cutting as desired on the job. Custom colors available. Cut off flush with surface of hardened concrete. **SAFE LOADS: 3000, 7500, and 25,000 lb**
	 TAPER TIE	Used where specs require or permit complete removal of tie from concrete. Tie is reusable. **SAFE LOADS: 7500 to 50,000 LB**
	 THREADED BAR WITH UNATTACHED SLEEVE	Standard 20-ft lengths cut to meet project requirements. Double nuts may be needed for higher load capacities. Bar is reusable. **SAFE LOADS: 10,000 to 32,500 lb**
Internally Disconnecting Ties	 SHE-BOLT TIE	Heavy duty, with reusable end bolts. No internal spreader, but external spreader bracket available. **SAFE LOADS: 4900 to 64,000 lb up to 155,000 in high strength steel**
	 TWO-STRUT COIL TIE WITH CONES	Designed for medium to heavy construction. With or without cone spreaders. Bolts reusable. **SAFE LOADS; two-strut, 3000 to13,500 lb; four-strut, 9000 to 27,000 lb**

Some common one-piece and internally disconnecting ties. Safe loads, taken from manufacturers' recommendations, are based on a safety factor of 2. Wedges, nuts, or other holding devices are shown schematically and may vary from that pictured. A wide range of safe loads indicates that there are several diameters, grades of steel, or different fastener details.

Source: Formwork for Concrete – Seventh Edition, M.K. Hurd, ACI Committee 347.

ONTARIO FORMWORK ASSOCIATION

ADVANTAGES

In short, we are an important voice for the Formwork Industry in Ontario. We are the communications link for our members and provide representation on important issues before all levels of government, regulatory boards and commissions. The Association has been given responsibility for employer/employee relation including labour contract negotiations, including the general administration and interpretation of contracts and arbitration of labour disputes. In all our work we place special emphasis on employee health and safety issues.

The Formwork industry takes enormous pride in the professional and creative skills of our craftsmen and our outstanding record for quality workmanship. The Association is committed to maintaining and enhancing our reputation for quality management and the development of state-of-the-art management systems. We recognize that it is only through excellence – in management, in workmanship, in productivity and the innovative and creative development and application of technology that we can maintain and advance the leading-edge reputation and competitiveness of our membership!

In a highly competitive industry within a free-market economy, quality work and highly effective management skills are essential, not only to success, but to survival. It is the task of the Association to protect and enhance the industry's position of leadership and reputation for excellence. For this reason we encourage, promote and are actively involved in educational and training programs to constantly upgrade and improve the skills of both management and employees to keep both totally up to date with changes and innovation in the industry.

The Ontario Formwork Association has an excellent track record and we intend to maintain and build upon that record by accepting the challenges offered by international trade and the growing global market.

"We are an important voice of the formwork industry in Ontario"

OUR MEMBERS

Avenue Building Corporation

CIP Group Inc.

Consolidated 2000 Inc.

Delgant Construction Ltd

Dominion Forming Inc.

Forma-Con Construction

Hardwall Construction

Italform Limited

Maple Leaf Structural Limited

Paramount Structures Ltd

Premform Ltd

Resform Construction Ltd

T.F. Construction Ltd

Trio Forming Ltd

Verdi Inc.

CONCRETE FORMWORK ASSOCIATION OF ONTARIO

The Concrete Forming Association of Ontario (CFAO) was established in 1971and speaks for the interests of companies working in the institutional, commercial, industrial (ICI) sector of the construction industry. It accounts for the bulk of cast-in-place construction work in the Golden Horseshoe area, the hub of Ontario's economy. CFAO works in partnership with men and women of:

- Labourers' International Union of North America
- United Brotherhood of Carpenters and Joiners of America
- International Union of Operating Engineers

Our Association sits as members of the Advisory Board of the General Contractors' Section of the Toronto Construction Association.

Our Association also sits on the Carpenters' and Labourers' Employer Bargaining Agencies in negotiating Provincial collective agreements, to establish wages, etc., that apply to our sector.

In addition, we are founding members of the recently established industry promotional body, the Ontario Cast-In-Place Concrete Development Council (OCCDC).

MEMBERS OF THE CFAO

Alliance Forming Ltd.
Avenue Building Corporation
Caledon Structures Inc.
Delgant Construction Limited
Dell-Core Equipment Ltd.
Forma-Con Construction
Hardrock Forming Co.
Outspan Concrete Structures Ltd.
Premform Group Inc.
Rapid Forming Inc.
Res 2000 Structures Inc.
Structform International Ltd.
Yukon Construction Inc.

Awards Given Each Year at Ryerson University

The Concrete Forming Association of Ontario, in conjunction with Ryerson University, established a trust fund for Ryerson students who have completed their first or second year of the Civil Engineering program and who are continuing on into the second and third year on a full time basis in the immediate year following.

CFAO sponsorships include:

1) **CONCRETE FORMING ASSOCIATION AWARD** to a second or third year student with demonstrated experience or background in the construction industry and a clear academic standing.

2) **CONCRETE FORMING ASSOCIATION AWARD** to a second or third year student with demonstrated experience or background in the construction industry and a clear academic standing.

3) **CONCRETE FORMING ASSOCIATION OF ONTARIO (FEMALE) AWARD** presented to a female student with the highest standing in second year environmentally related courses including hydrology, fluid mechanics, hydraulic engineering and environmental science for engineers.

4) **DAN DORCICH MEMORIAL AWARD** (Sponsored by Concrete Forming Association of Ontario) for a student with demonstrated interest, experience or background in the construction industry and a clear academic standing.

5) **NICK BARBIERI MEMORIAL AWARD** (Sponsored by Concrete Forming Association of Ontario) for a student who has demonstrated interest, experience or background in the construction industry and a clear academic standing.

CFAO

ARCHITECTURAL MERIT AWARD 2009

Engineering Technology Building, McMaster University

OWNER:
McMaster University

ARCHITECT OF RECORD:
Vermeulen Hind Architects

ENGINEER OF RECORD:
Halcrow Yolles

GENERAL CONTRACTOR:
Bird Construction Company

MATERIAL SUPPLIER:
Lafarge

ADDITIONAL PARTICIPANTS:
- AGF Albrecht Reinforcing Steel
- Aluma Systems Canada Inc.
- Belmont Concrete Finishing
- Carpenters Local 18
- Enermodal Engineering
- Ironworkers Local 736
- LIUNA Local 837
- National Concrete Accessories
- Reimar Forming Construction

Ontario Concrete *Awards*

CONCRETE TECHNICAL INFORMATION

OCCDC

CONCRETE EXPOSURE CLASSES

Determination of the minimum concrete performance properties is based upon identifying the following key requirements:

- **Applicable Exposure Conditions** – The designer must assess the environmental conditions that the concrete will be exposed to during its service life. Direct input is also required from the Owner regarding possible future uses since they can significantly affect the exposure class selection
- **Structural Requirements** – The designer must determine the minimum concrete properties required to meet the applicable loading conditions
- **Architectural Requirements** – The designer must consider the effects of selecting various architectural finishes on concrete material properties.
- **Minimum Durability Requirements** – Based upon the designer's assessment of the exposure conditions, the CSA A23.1 standard sets minimum concrete properties.

In cases where these various factors result in differing material properties, the designer must select the most stringent requirement as the minimum concrete performance requirement.

CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Tables 1 – 4 outline the minimum durability requirements.

References:
1 CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International

CSA A23.1 – Table 1
Definitions of C, F, N, A, and S exposure classes

(See Clauses 4.1.1.1.1, 4.1.1.5, 4.4.4.1.1.1, 4.4.4.1.1.2, 6.6.7.5.1, 8.4.1.2 and Tables 2 and 12.)

C-XL	Structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, with higher durability performance expectations than the C-1, A-1 or S-1 classes.
C-1	Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions. Examples: bridge decks, parking decks and ramps, portions of marine structures located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools.
C-2	Non-structurally reinforced (i.e. plain) concrete exposed to chlorides and freezing and thawing. Examples: garage floors, porches, steps, pavements, sidewalks, curbs, and gutters.
C-3	Continuously submerged concrete exposed to chlorides but not to freezing and thawing. Examples: underwater portions of marine structures.
C-4	Non-structurally reinforced concrete exposed to chlorides but not to freezing and thawing. Examples: underground parking slabs on grade.
F-1	Concrete exposed to freezing and thawing in a saturated condition but not to chlorides. Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
F-2	Concrete in an unsaturated condition exposed to freezing and thawing but not to chlorides. Examples: exterior walls and columns.
N	Concrete not exposed to chlorides nor to freezing and thawing. Examples: footings and interior slabs, walls and columns.
A-1	Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas may be generated. Examples: reinforced beams, slabs and columns over manure pits and silos, canals, pig slats, access holes, enclosed chambers, and pipes that are partially filled with effluents.
A-2	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure. Examples: reinforced walls in exterior manure tanks, silos and feed bunkers, exterior slabs.
A-3	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure in a continuously submerged condition. Concrete continuously submerged in municipal or industrial effluents. Examples: interior gutter walls, beams, slabs and columns, sewage pipes that are continuously full (e.g., force mains), and submerged portions of sewage treatment structures.
A-4	Non-structurally-reinforced concrete exposed to moderate manure and/or silage gases and liquids, without freeze-thaw exposure. Examples: interior slabs on grade.
S-1	Concrete subjected to very severe sulphate exposure (Tables 2 and 3).
S-2	Concrete subjected to severe sulphate exposure (Tables 2 and 3).
S-3	Concrete subjected to moderate sulphate exposure (Tables 2 and 3).

Notes:
(1) "C" classes pertain to chloride exposure.
(2) "F" classes pertain to freezing and thawing exposure without chlorides.
(3) "N" class is exposed to neither chlorides nor freezing and thawing.
(4) "A" class pertains to agricultural, municipal or industrial projects exposed to human or animal wastes.
(5) All classes of concrete, exposed to sulphates, shall comply with the minimum requirements of "S" class noted in Tables 2 and 3.

CSA A23.1 – Table 3
Additional requirements for concrete subjected to sulphate attack*

(See Clauses 4.1.1.1.1, 4.1.1.6.2, 4.1.1.6.3, 8.4.1.2 and Tables 1.)

Class of exposure*	Degree of exposure	Water soluble sulphate (SO_4)† in soil sample, %	Sulphate (SO_4) in groundwater sample, mg/L‡	Water soluble sulphate (SO_4) in recycled aggregate sample, % §	Cementing materials to be used**
S-1	Very severe	> 2.0	> 10,000	> 2.0	HS or HSb
S-2	Severe	0.20 – 2.0	1,500 – 10,000	0.60 – 2.0	HS or HSb
S-3	Moderate	0.10 – 0.20	150 – 1,500	0.20 – 0.60	MS, MSb, LH, HS, or HSb

* For sea water exposure, see Clause 4.1.1.5.
† As per CSA A23.2-3B.
‡ As per CSA A23.2-2B.
§ Cementing material combinations with equivalent performance maybe used (see Clauses 4.2.1.2, 4.2.1.3, and 4.2.1.4). Type HS cement shall not be used in reinforced concrete exposed to both chlorides and sulphates. Refer to Clause 4.1.1.3.

CSA A23.1 – Table 2
Requirements for C, F, N, R, S and A classes of exposure

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.2.1, 4.3.1, 7.4.1.1, 8.8.3, and 8.8.6.1, and Table 1.)

Requirements for specifying concrete

Class of exposure*	Maximum water-to-cementing materials ratio†	Minimum specified compressive strength (MPa) and age (d) at test†	Air content category as per Table 4	Curing type (see Table 20): Normal concrete	HVSCM 1	HVSCM 2	Chloride ion penetrability test requirements and age at test‡
C-XL	0.37	50 within 56 d	1 or 2§	3	3	3	< 1,000 coulombs within 56 d
C-1 or A-1	0.40	35 at 28 d	1 or 2§	2	3	2	< 1,500 coulombs within 56 d
C-2 or A-2	0.45	32 at 28 d	1	2	2	2	
C-3 or A-3	0.50	30 at 28 d	2	1	2	2	
C-4** or A-4	0.55	25 at 28 d	2	1	2	2	
F-1	0.50	30 at 28 d	1	2	3	2	
F-2	0.55	25 at 28 d	2††	1	2	2	
N‡‡	For structural design	For structural design	None	1	2	2	
S-1	0.40	35 at 56 d	2	2	3	2	
S-2	0.45	32 at 56 d	2	2	3	2	
S-3	0.50	30 at 56 d	2	1	2	2	

* See Table 1 for description of classes of exposure.
† The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementing materials ratio. The water-to-cementing materials ratio shall not be exceeded for a given class of exposure.
‡ In accordance with ASTM C 1202. An age different from that indicated may be specified by the owner. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, but without calcium nitrite, shall be prequalified to meet the requirements for the permeability index in his Table.
§ Use Category 1 for concrete exposed to freezing and thawing. Use air content Category 2 for concrete not exposed to freezing and thawing.
** For class of exposure C-4, the requirement for air entrainment should be waived when a steel trowelled finish is required. The addition of
supplementary cementing materials may be used to provide reduced permeability in the long term, if that is required.
†† Interior ice rink slabs and freezer slabs with a steel trowelled finish have been found to perform satisfactory without entrained air.
‡‡ To allow proper finishing and wear resistance, Type N concrete intended for use in an industrial concrete floor with a trowelled surface exposed to wear shall have a minimum cementing materials content of 265 kg/m3.

CSA A23.1 – Table 4
Requirements for the air content categories

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.2.3.2.2., 4.3.1.1, 4.3.3.1, 4.3.3.2, 4.4.4.1.1.1, and Tables 2)

Air content category	Range in air content* for concrete with indicated nominal maximum sizes of coarse aggregate, %: 10 mm	14 – 20 mm	28 – 40 mm
1†	6 – 9	5 – 8	4 – 7
2	5 – 8	4 – 7	3 – 6

* At the point of discharge from the delivery equipment, unless otherwise specified.
† For hardened concrete, see Clause 4.3.3.2.

Notes:
(1) The above difference in air contents has been established based upon the difference in mortar fraction volume required for specific coarse aggregate sizes.
(2) Air contents measured after pumping or slip forming may be significantly lower than those measured at the end of the chute.

COLD WEATHER CONCRETING


Photo courtesy of CAC

Weather conditions can have a dramatic effect on both the setting time and concrete placing, finishing and protection systems that must be followed for proper concrete placement. Cold weather concreting conditions are typically defined as:

- When the air temperature is ≤ 5°C.
- Or when there is a probability that the temperature may fall below 5°C within 24 hours of placing the concrete.

Because the hydration process is a chemical reaction it is strongly affected by ambient air and subgrade/formwork temperatures. At low temperatures concrete gains strength and sets very slowly and must be adequately protected from freezing and thawing. Concrete that is allowed to freeze while in its plastic state can have its potential strength reduced by more than 50% and its durability properties will be dramatically reduced. Concrete must achieve at least 3.5 MPa before it is frozen and should obtain at least 20 MPa before it is exposed to multiple freeze/thaw cycles.

General procedures for cold weather concreting include:

- Removing all ice and snow from the subgrade or formwork.
- Supplying the necessary supplemental heat required to ensure that forms, subgrades, and reinforcing steel is maintained a minimum temperature of 5°C well prior to the concrete placement.
- Ordering concrete with a temperature between 10°C – 25°C.
- Concrete should be ordered using the lowest practical water slump since this will reduce bleeding and setting times. Chemical admixture can still be used to improve the workability of the concrete.
- Chemical admixtures and mix design modifications can be used to offset the slower setting times and strength gain of concrete during cold weather conditions. Considerations should be given to ordering concrete that will obtain higher early strengths.
- Concrete temperature must be maintained at a minimum of 10°C for the full curing period.
- The surface of the concrete should not be allowed to dry out while it is still plastic since this may cause plastic shrinkage cracking. The longer set times encountered during cold weather combined with the effects of hot dry air from heaters being blown along the top surface of the concrete significantly increase this risk.
- Wet curing methods are typically not recommended during cold weather conditions since the concrete will not have a sufficient time period to air dry before the first freeze/thaw cycle.
- The possibility of thermal cracking must be considered when the heating supplied during the curing period is going to be suspended. Concrete should not be allowed to cool at a rate outside the limits listed in CSA A23.1 Table 21.

Special care should be taken with concrete test specimens used for the acceptance of the concrete. The initial test specimens shall be stored in a controlled environment that maintains the temperature at 20 ± 5°C as per CSA A23.1/.2 requirements.


Photo courtesy of Lafarge Camada Inc.

Caution regarding the use of portable gas fired heaters:

Plastic concrete exposed to a carbon dioxide source (CO_2) during the concrete placing, finishing and curing period will develop a soft, chalky, carbonated surface (known as dusting). Carbon Dioxide is an odourless and colourless gas that is heavier than air and is produced by all forms of combustion. Typical sources include: open flame heaters (stacks must be vented to outside), and internal combustion engines (e.g. on trucks, power trowels, concrete buggies, etc.). Precautions must therefore be taken to properly vent the placement area.

CSA A23.1 – Table 21
Maximum permissible temperature differential between concrete surface and ambient (wind up to 25km/h)
(see Clauses 7.4.2.3 and 7.4.2.5.3.4)

	Maximum permissible temperature differential, °C				
	Length to height ratio of structural elements*				
Thickness of concrete, m	0†	3	5	7	20 or more
< 0.3	29	22	19	17	12
0.6	22	18	16	15	12
0.9	18	16	15	14	12
1.2	17	15	14	13	12
> 1.5	16	14	13	13	12

* Length shall be the longer restrained dimension and the height shall be considered the unrestrained dimension.
† Very high, narrow structural elements such as columns.

References:
1 CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International
2 Ontario Building Code – 2006, Ontario Ministry of Municipal Affairs and Housing – Housing Development and Buildings Branch
3 Concrete Digest – 2nd Edition, Ready Mixed Concrete Association of Ontario
4 Concrete in Practice #27 – Cold Weather Concreting, National Ready Mixed Concrete Association

CONCRETE TECHNICAL INFORMATION

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HOT WEATHER CONCRETE


Photo courtesy of CAC

Weather conditions can have a dramatic effect on both the setting time and concrete placing, finishing and protection systems that must be followed for proper concrete placement. Hot weather concreting conditions typically include:

- High ambient air temperatures (≥ 28°C)
- Low relative humidity conditions
- High wind speeds
- Solar radiation or heat gain

These conditions can result in the following challenges for the concrete contractor:

- Increased concrete water demand
- Accelerated concrete slump loss
- Increased rate of setting leading to placing and finishing difficulties
- Increased tendency for plastic shrinkage cracking
- Increased concrete temperature resulting in lower ultimate strength
- Increased potential for thermal cracking

The first step that must be taken is to identify when hot weather concreting conditions may apply and modify the normal concrete placing and finishing procedures accordingly. Possible steps that may be taken include:

Preparation

ACI recommendations regarding the pre-wetting of the subgrade have recently changed so that this procedure is not typically recommended. The only exception is during hot weather conditions were plastic shrinkage cracking may be an issue. The subgrade should be pre-wetted and forms and reinforcing steel should be dampened prior to concrete placing (there should be no standing water). The purpose of these actions is to prevent the absorption of water from the concrete into the subgrade.

Ordering

Inform the ready mixed concrete producer of your placing schedule and whether a chemical retarder will be required. For exposed flatwork the use of retarding admixtures or supplementary cementing materials should be discussed with the concrete producer. In extreme cases the concrete temperature may also be lowered by using chilled water, ice or liquid nitrogen (extra charges will apply).

Slump

A concrete consistency (slump) which allows for rapid placement and consolidation should be considered. Chemical admixtures such as super-plasticizers can dramatically improve the concrete slump and reduce placement times.

Placing

After the concrete is properly mixed ensure that it is discharged as soon as possible. Consider the use of large crews to accelerate placement rates.

Finishing

In cases where protection against rapid evaporation of water from the concrete surface is a concern, (Figure 1) consider the use of one or more of the following actions:

- Erect sunshades and wind breaks
- Cover the surface with white polyethylene sheets
- Apply fog spray
- Place and finish at night or early morning
- Apply temporary evaporation retarder after the screeding operation

Figure 1

Estimation of rate of evaporation of moisture from a concrete surface

(See Clause 7.4.2.2.)

To use this chart:
1. Enter with air temperature, move up to relative humidity.
2. Move right to concrete temperature.
3. Move down to wind velocity.
4. Move left; read approx. rate of evaporation.

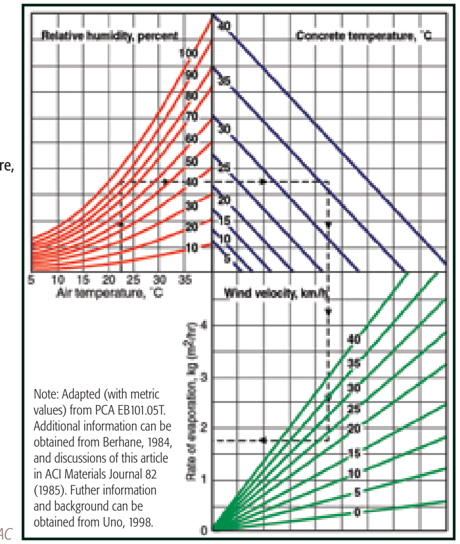


Photo courtesy of CAC

Curing

Curing should be started as soon as the concrete has set enough to avoid any surface damage. Concrete should be cured for at least 7 consecutive days after placing. Ensure that the concrete is kept moist throughout the curing process (see technical bulletin on curing options).

Testing

To avoid inaccurate strength test results, the initial test specimens shall be stored in a controlled environment that maintains the temperature at 20 ± 5°C as per CSA A23.1/.2 requirements. Concrete test cylinders that exceed these temperature requirements typically exhibit much lower 28 day strengths.

References:
1 CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International
2 Concrete Digest – 2nd Edition, Ready Mixed Concrete Association of Ontario
3 Concrete in Practice #12 – Hot Weather Concreting, National Ready Mixed Concrete Association

PROPER CONCRETE JOINTING DETAILS TO CONTROL RANDOM CRACKING

Shrinkage is an unavoidable fact of concrete construction. The key to a successful concrete project is understanding how to minimize shrinkage and knowing what steps to take to avoid random concrete cracking.

The primary factors that result in concrete shrinkage and/or cracking include:

- Settlement of the sub-grade
- Chemical shrinkage of the concrete
- Temperature and moisture changes in the concrete
- Application of loads to the concrete surface
- Restraint of concrete movement during either expansion or contraction.

The actual amount of concrete shrinkage is governed by:

- The concrete's raw constituents
- The unit water content of the mix
- The drying conditions that the concrete is exposed to
- The size and shape of the concrete element.

Once these facts are known, the designer and contractor can properly address concrete shrinkage by selecting the appropriate concrete thickness and layout, installing the necessary concrete jointing systems and utilizing the correct amount of reinforcement in suitable locations.

Methods to minimize the volume change of concrete and reduce internal stresses from a mix design standpoint include:

- Lowering the unit water content of the concrete as much as practical
- Using the largest practical size of coarse aggregate in order to minimize the paste content of the mix
- Utilizing well graded aggregate blends which exhibit low shrinkage
- Minimizing the water demand of the concrete by utilizing supplementary cementing materials
- Avoid admixtures that increase drying shrinkage (i.e. calcium chloride based accelerators).

Basics of Unreinforced Concrete Slab-on-Grade Construction

As stated previously, concrete shrinks in all directions as it cures. Whether the concrete will crack due to material shrinkage alone is dependent on the shape of the concrete, the thickness of the concrete and the restraint supplied by subgrade or adjacent elements. If the concrete is free to move then no stresses are created and the concrete doesn't crack. To avoid random concrete cracking we utilize a system of joints (isolation, contraction & construction) to force the concrete cracking to follow specific lines (See adjacent photos).

The basic rules for layout of these joints are as follows:

- The maximum joint spacing should not exceed 24 to 36 times the thickness of the slab and should not exceed 4.5 m as per CSA A23.1
- The resulting panels created by these joints should be as square as possible. The length/width ratio of the panels should never exceed 1.5
- Joint depths should be at least ¼ the depth of the slab
- Contraction joints should be located at all "re-entrant" corners (corners with angles greater than 90°) to prevent radial cracking
- "T" intersections of contraction joints should be avoided since the random cracks will tend to continue through into the next slab.

The basic jointing systems are as follows:

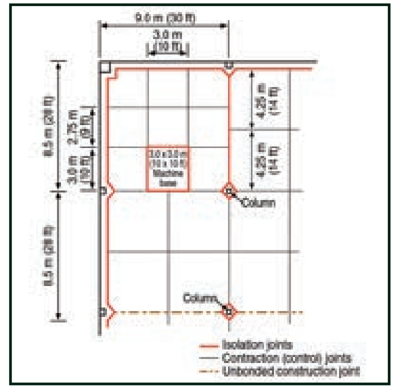
Isolation Joints: Joints that permit both horizontal and vertical movement between the slab and the adjacent concrete (see diagram 1). The purpose of this joint is to completely separate the two concrete elements (since they may move independently of each other) and to provide space for both expansion and contraction of the concrete. These joints are typically 13 mm in thickness and are constructed of a compressible material.

Contraction Joints: Joints that permit horizontal movement of the slab and induce controlled cracking at preselected locations (see diagram 2). These joints are typically created by grooving the concrete while it is still in the plastic state or cutting the concrete in its hardened state once it has obtained sufficient strength (typically 4 – 12 hours after placement).

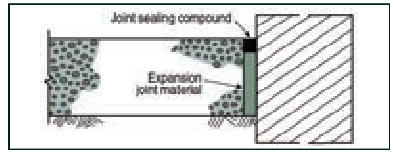
Construction Joints: Joints that are stopping places in the process of construction (see diagram 3). The person designing the joint layout has the option with construction joints to have them act as a contraction joint and allow horizontal movement only (diagram 3-b) or to create a fully bonded joint with deformed rebar and not permit either horizontal or vertical movement (diagram 3-c).

Proper jointing layout is performed before the concrete is placed by utilizing the basic rules above to determine the maximum joint spacing and then reviewing the plan view of the project to determine the proper locations of the three basic jointing types (see below). Concrete placement should never occur until a proper joint layout drawing has been prepared, reviewed and approved.

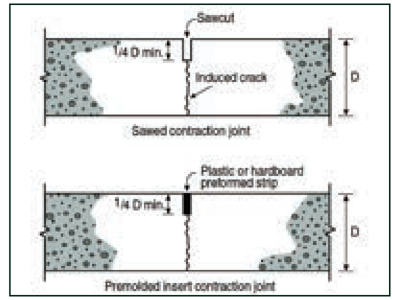
TYPICAL JOINT LAYOUT



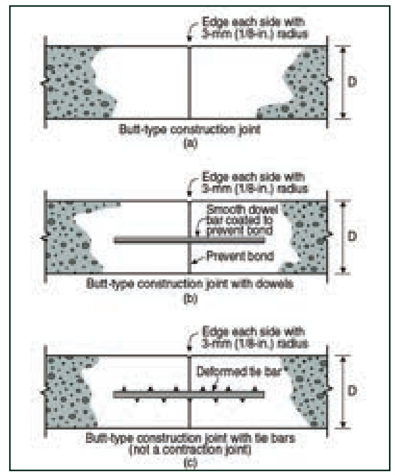
ISOLATION JOINT – DIAGRAM 1



CONTRACTION JOINT – DIAGRAM 2



CONSTRUCTION JOINT – DIAGRAM 3



References:
1 CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International
2 Concrete Digest – 2nd Edition, Ready Mixed Concrete Association of Ontario
3 Slabs on Grade, ACI Concrete Craftsmen Series CCS-1, American Concrete Institute
4 Concrete in Practice #6 – Joints in Concrete Slabs on Grade, National Ready Mixed Concrete Association

CONCRETE TECHNICAL INFORMATION

CURING CONCRETE


Photo courtesy of RMCAO

Curing is defined as "maintenance of a satisfactory moisture content and temperature in the concrete for a period of time immediately following placing and finishing so that the desired properties may develop." Early curing is critical when the concrete will be exposed to harsh Canadian weather conditions since it dramatically affects the permeability and durability of the concrete. In some instances curing must be initiated even before the finishing operations are complete to provide the necessary concrete properties.

Since the strength and durability properties of concrete are set by the chemical reactions of the various components during the hydration process, there are three key factors to proper curing.

- **Moisture** – Having sufficient moisture to ensure the hydration process continues
- **Temperature** – Maintaining a sufficient temperature (≥10°C) to ensure that the chemical reaction continues
- **Time** – Maintaining both the moisture and temperature requirements for a minimum period of time (3 – 7 days – See CSA A23.1 – Table 20) to ensure that the durability properties fully develop. Curing needs to be initiated as soon as the finishing operations are complete and the surface will not be damaged by the curing operation.

General Notes Regarding Concrete Curing:

1. Alternating cycles of wetting and drying during the curing process is extremely harmful to the concrete surface and may result in surface crazing and cracking. This should be avoided at all costs.

2. A 28 day air drying period is recommended immediately following the 28 day curing period to provide the necessary freeze/thaw resistance for the concrete. Curing methods that result in fully saturated concrete, which will be exposed to freeze/thaw cycles once the curing period is over, may result in premature deterioration of the concrete (even if the concrete is properly air entrained).

3. Concrete with low W/CM ratios (≤ 0.40) may not have sufficient free moisture in the mix to allow for the use of "moisture loss prevention" curing methods. This situation should be reviewed prior to the start of the project.

Curing of concrete can be completed by two basic methods:

- Preventing the loss of moisture from the concrete
- Keeping the exposed surface continuously wet

CSA A23.1 – Table 20
Allowable curing regimes
(see Clause 4.1.1.1.1, 7.4.1.1, 7.4.1.7.1, and Table 2)

Curing Type	Name	Description
1	Basic	3 d at ≥ 10°C or for a time necessary to attain 40% of the specified strength.
2	Additional	7 d at ≥ 10°C and for a time necessary to attain 70% of the specified strength. When using silica fume concrete, additional curing procedures shall be used. See Annex I, Clause 1.3.13.
3	Extended	A wet-curing period of 7 d. The curing types allowed are ponding, continuous sprinkling, absorptive mat or fabric kept continuously wet.

References:
1 CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International
2 Ontario Building Code – 2006, Ontario Ministry of Municipal Affairs and Housing – Housing Development and Buildings Branch
3 Concrete Digest – 2nd Edition, Ready Mixed Concrete Association of Ontario
4 Concrete in Practice #11 – Curing In-Place Concrete, National Ready Mixed Concrete Association

Possible curing methods are outlined in the following table:

MOISTURE LOSS PREVENTION

Curing Compounds

- Form a membrane over the top surface of the concrete preventing moisture loss
- Must be applied at the manufacturers suggested application rate
- Should be applied in two applications with the second being at right angles to the first to ensure uniform coverage
- Should be applied as soon as the concrete surface is finished and when there is no free water on the surface
- Curing compounds can effect the "bond" of some floor coverings
- Confirm that this curing method is suitable for the final floor covering application

Plastic Sheeting

- Ensure that the plastic sheeting covers 100% of the concrete surface and that it is adequately sealed at the edges to prevent moisture loss
- Select the appropriate colour (white, black, or clear) of the plastic based upon the ambient air conditions
- If uniform colour is a requirement for the project ensure that the plastic is not placed directly on the concrete surface
- Ensure that plastic sheeting is not damaged by subsequent construction activities during the curing period

Leaving Formwork In Place

- This system is most effective for vertical elements (walls, columns, beams, etc). Care must be taken to also protect the top surface of the concrete appropriately
- "Breaking" or "Releasing" the formwork dramatically reduces the effectiveness of this curing method since air flow is now possible between the concrete and the formwork
- If uniform colour is an issue then a uniform curing time and temperature must also be maintained and form removal scheduled accordingly

SUPPLYING SUPPLEMENTAL MOISTURE

Water Ponding

- Flooding of the concrete surface to provide both moisture and a uniform curing temperature
- Curing water should not be more than 12°C cooler than the concrete temperature to avoid the possibility of thermal cracking
- The water must cover the entire concrete surface

Water Sprinkling

- Spraying water over the concrete surface. The entire concrete surface must be wet for this method to be effective
- The concrete surface must have sufficient strength to avoid damaging the surface
- Excess water will run off the concrete and must be drained away
- This protection method can be adversely affected by high winds which prevent proper curing on the "upwind" side

Wet Burlap

- Pre-soaked burlap is applied to the concrete surface and is covered with plastic to prevent moisture loss or water is reapplied as necessary to prevent the material from drying out
- Burlap should be rinsed prior to its first use to avoid possible staining
- Materials utilizing both geotextile fabric and plastic top coatings can be reused throughout the project

Wet Sand

- Wet loose material such as sand can be used to cure concrete slabs and footings
- The sand thickness must be sufficient to prevent moisture loss at the concrete surface or the sand must be wetted throughout the curing period

TEN STEPS TO DURABLE EXTERIOR FLATWORK

Exterior concrete flatwork is both beautiful and durable when it is properly placed, finished and protected. In order to ensure that your project is a complete success we strongly suggest you follow these ten steps:

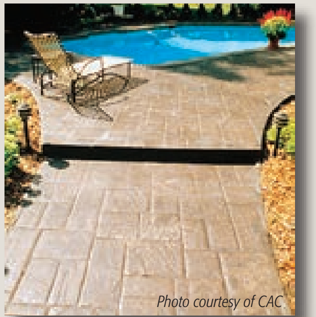


Photo courtesy of CAC

1. Use the right concrete.

The Ontario Building Code requires that all exterior concrete shall have a minimum 28-day compressive strength of **32 MPa** and a maximum water/cementing materials ratio (W/CM) of 0.45 (C-2 Concrete as per CSA A23.1) and 5-8% air for freeze-thaw durability. **25 MPa concrete should never be used!** Concrete should only be ordered from an RMCAO member company.

2. Use the right contractor.

Use a contractor who has been trained to an industry certification program such as ACI Concrete Flatwork Finisher/ Technician (or similar). Ask for past examples of their work and references. Call the references and visit projects that have gone through at least two winters.

3. Avoid placing concrete late in the season.

The concrete must have sufficient time to both cure properly (28 days) and to dry out (additional 28 days) before being exposed to freeze-thaw cycles. Early in its life, concrete contains excess moisture in order to provide the contractor with the slump necessary to place the material. If the concrete is allowed to freeze when this excess moisture is still present, the effects of air entrainment are dramatically reduced due to the fact that the concrete is completely saturated with water. Because of this, concrete placements from October on should be considered very carefully or avoided.

4. Avoid placing in hot or cold temperature extremes.

Concrete placed in hot weather and low humidity conditions can dry prematurely at the surface adding to finishing problems. Cold weather can also greatly reduce durability if the concrete is not placed, finished, protected and cured properly.

5. Ensure that the subgrade is properly prepared.

The subgrade must be properly graded and compacted in order to provide uniform support to the concrete slab. Subgrade settlement after concrete placement will lead to uncontrolled cracking.

6. Do not finish the concrete while the bleed water is still present.

This creates two significant problems. First, the excess water is physically worked back into the concrete paste on the surface dramatically increasing the W/CM and decreasing the concrete's strength and durability. Secondly, this action tends to seal the surface of the concrete causing all of the remaining bleed water to be trapped a few millimeters below the concrete surface. Once the concrete is exposed to its first winter, scaling will occur in this weak layer.

7. Do not overfinish or overwork the concrete surface.

Repeated troweling or finishing operations continue to bring additional cement paste to the surface, which weakens it. This paste layer then scales or mortar flakes very easily. The best procedure for all exposed concrete is to strike-off the surface, bullfloat the concrete before the bleed water appears and apply a broom texture to the surface once the concrete has gained sufficient stiffness. The use of **power trowels is not recommended** for exterior flatwork. If further finishing is performed (not recommended) ensure that a magnesium float is used on all air-entrained concrete! Steel trowels should never be used on exterior concrete.

8. Install proper control joints to prevent uncontrolled cracking.

All joints should be cut or formed to at least one-quarter (¼) of the slab thickness. Layout the locations of all control joints before the concrete placement starts! This advanced planning will ensure that there is no confusion when it is time to install the control joints and it may also indicate that the slab size should be modified in order to optimize the joint layout. Ensure

Photo courtesy of CAC

that you avoid "T-Joints" and "re-entrant corners" at all times. The spacing between joints should be between 24 to 36 times the slab thickness (to a maximum of 4.5 m) and should be ¼ depth minimum. Sawcutting should be completed **as soon as the concrete can be cut** (4 to 12h) without causing raveling.

9. Cure the concrete immediately after finishing.

Proper concrete curing addresses many defects that can be found in slab-on-grade concrete construction. Curing is required for a minimum of 7 days (as per CSA A23.1) on exposed concrete. Be sure that the curing compound is not watered down and that care is taken to apply the correct amount. **This is the most commonly overlooked part of the finishing process.** *The only caution regarding curing relates to work that is completed late in the fall since care must be taken to avoid having a fully saturated concrete when freezing can occur.*

10. Did we mention curing?

This point can not be overstated. All concrete must be properly cured in order to develop the necessary durability properties required to resist Canadian weather conditions. Owners may also wish to consider the use of concrete sealers to prevent the ingress of chlorides, oils and water into the concrete. These materials, when properly applied, can significantly lengthen the life of exterior concrete.

References:

1 CSA A23.1-09 – Concrete Materials and Methods of Concrete Construction, Canadian Standards Association International

2 Concrete Digest – 2nd Edition, Ready Mixed Concrete Association of Ontario

3 Doing Driveways Right the First Time, Concrete Construction, July 1998

4 De-icers and Concrete Scaling, Concrete Construction, November, 1965

RMCAO — VOICE OF THE CONCRETE INDUSTRY

OCCDC

WHO WE ARE

The Ready Mixed Concrete Association of Ontario was formed in 1959 to act in the best interest of Ontario's ready mixed concrete producers and the industry in general. It is fully funded by the membership (Active and Associate) and provides a broad range of services designed to benefit its members and the industry in general.

With a total membership of about 180 companies, it is recognized as the authoritative voice of the ready mixed concrete industry in Ontario.

The Association is governed by a Board of 13 Directors, five of whom represent different geographical parts of the Province, and two elected Chair and Vice Chair of the Associate Members. Standing committees address the many and varied concerns of specific interest to the industry.

RMCAO ACTIVITIES

- Actively involved in Codes & Standards development with CSA
- RMCAO Plant Certification
- Development of CMATS™, CANPav™ and an SCC Cost Calculator
- Technical Publications
- Educational Activities:
  - ACI Field Testing Technician
  - ACI Concrete Flatwork Finishing/Technician
  - Concrete College
  - RMCAO Driver Certification
- Gold Seal Concrete Course
- Pavement Evaluation

WHAT WE DO

Marketing and Promotion – utilizing its technical and promotional expertise and resources, the RMCAO marketing programs reach far into all private and government sectors. The marketing plan encompasses Insulating Concrete Forming Systems, the Agricultural, Residential and ICI sectors, Municipal, Provincial and Commercial Pavements, Codes and Standards and Structural Concrete.

Government Relations – the concrete industry deals with many different Ministry offices, as there are several separate and distinct issues that impact the industry both on a direct and indirect basis. The Association maintains close **affiliations** with provincial and municipal government at all levels to monitor any changes and to work effectively for the betterment of its members.

www.rmcao.org is an essential technical resource for the industry. The site includes:

- **Feature Items** – highlights current and future issues and events
- **Directory of Members** – contains a list of all current members complete with links to their websites
- **Calendar** – keep up-to-date on all meetings, events, etc.
- **Technical Information** – allows you to download documents when you need them
- **Awards and Showcase Home Program** – up-to-date information on what's happening

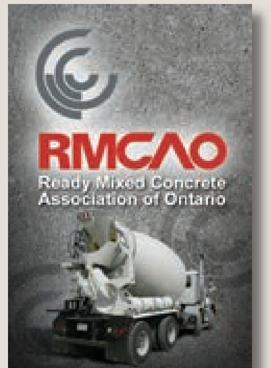
Social media sites:

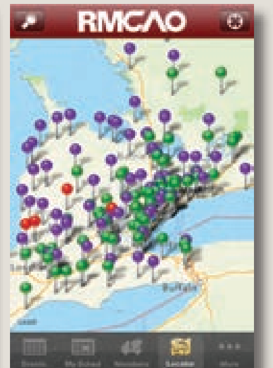
http://www.facebook.com/ConcreteOntario
https://twitter.com/concreteontario
http://www.linkedin.com/company/ready-mixed-concrete-association-of-ontario
http://www.youtube.com/concreteontario

MOBILE APPLICATION

RMCAO has developed and released a mobile app entitled "**Concrete Ontario**" for both the iPhone and BlackBerry smart phones. The **Concrete Ontario** app is available for download free of charge on both platforms and includes:

- Technical Library
- Events Calendar
- Membership Directory
- GPS Plant Locator





RMCAO

Ready Mixed Concrete Association of Ontario
365 Brunel Road, Unit 3
Mississauga ON L4Z 1Z5
Phone: 905-507-1122
Fax: 905-890-8122
info@rmcao.org

www.rmcao.org

WORKER TRAINING PROGRAMS

CARPENTERS UNION

WHO WE ARE

Carpenters' District Council of Ontario

Fourteen state-of-the-art Training Centres within the CDC's jurisdiction deliver the highest standard of Apprenticeship, Health and Safety, and Upgrade Training programs to thousands of Union members every year. The Carpenters' Union is the largest Training Delivery Agent of Carpentry Apprenticeship in the province.

Apprenticeship Programs:
- General Carpenter
- Floor Covering Installer
- Drywall Acoustic Mechanic & Lathing

Upgrade & Health & Safety Courses:
- Computers
- Confined Spaces
- Construction Math
- Door & Hardware – Mechanical & Electrified
- Elevated Work Platforms
- Estimating
- Fall Protection
- First Aid & CPR
- Foreperson / Supervisor
- Forklift – Tow Motor & All Terrain
- Formwork Carpentry
- Hoisting & Rigging
- Layout – Level, Transit, Total Station
- Print Reading – Commercial & Residential
- Propane
- Red Seal Certificate of Qualification Preparatory Course
- Solid Surfaces
- Scaffolding – Tube & Clamp & Systems
- Stair Building
- Steel Stud Framing
- Trim Carpentry
- Welding – to CWB certification
- WHMIS

LOCAL	PHONE/FAX	LOCAL	PHONE/FAX
Carpenters' District Council of Ontario	905-652-4140 Fax: 905-652-4139	Local 494 Windsor	519-258-5533 Fax: 519-258-2223
Local 18 (Hamilton)	905-522-0752 Fax: 905-522-0122	Local 785 Cambridge	519-653-7543 Fax: 519-653-2837
Local 18 (Niagara)	905-892-1877 Fax: 905-892-1809	Local 1256 Sarnia	519-344-2674 Fax: 519-336-4449
Local 27 Toronto	416-749-7440 Fax: 905-652-4139	Local 1669 Thunder Bay	807-344-0611 Fax: 807-345-2548
Local 93 Ottawa	613-745-1513 Fax: 613-745-3769	Local 1946 London	519-652-2992 Fax: 519-652-6733
Local 249 Kingston	613-384-3316 Fax: 613-384-3730	Local 1988 Smith Falls	613-283-5670 Fax: 613-275-2439
Local 397 Port Hope	905-885-0885 Fax: 905-885-0850	Local 2222 Goderich	519-524-6601 Fax: 519-524-5831
Local 2486 (Zone 2) Sault Ste. Marie	705-949-3170 Fax: 705-945-6087	Local 2486 Sudbury	705-673-3866 Fax: 705-675-7856

LABOURERS' INTERNATIONAL UNION OF NORTH AMERICA

LiUNA!
Ontario Provincial District Council

Phone: 289-291-3678
Fax: 289-291-1120
E-mail: opdc@liunaopdc.org
www.liunopdc.org

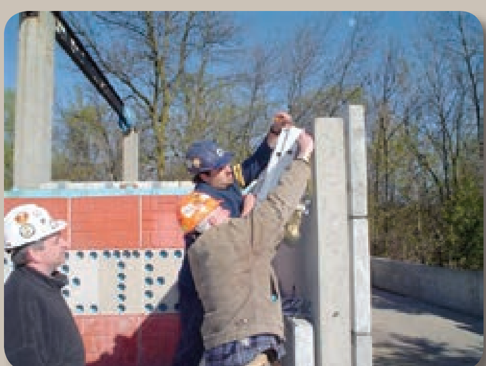
Local 183-Toronto
Local 247-Kingston
Local 493-Sudbury
Local 506-Toronto

Local 527-Ottawa
Local 607-Thunder Bay
Local 625-Windsor
Local 837-Hamilton

Local 1036-S. S. Marie
Local 1059-London
Local 1081-Cambridge
Local 1089-Sarnia

Strong, Proud, United

The Labourers' International Union through the Ontario Provincial District Council and their affiliated local unions listed above have, through training and education, presented the finest qualified and professional workforce to our construction/industrial partners throughout the Province of Ontario. Building on our over 100 years of experience and dedication to perfection, the Labourers' have contributed considerably to the establishment of Ontario as the best place in Canada to call home. We recognize the need for growth through learning and have established on a local level, five centres for education and training that ready the workforce that will build the future of Ontario. We strive, through our partnerships with management, to make the workplace a safer more productive environment by promoting strict adherence to provincially mandated and industry recognized standards which in turn ensure a long lasting relationship that is mutually beneficial in every facet.



IRONWORKERS

The Reinforcing Rodworker apprenticeship consists of 4000 hours in the field work experience including two terms of in-school training. The trade school intakes are basic (8 weeks) and advanced (4 weeks). Once the apprentice has completed the requirements of their contract they will challenge the Certificate of Qualification examination where they must obtain a minimum of 70% to change classification to Journeyman Reinforcing Rodworker.

Classes are offered throughout the year at the training center under the auspices of the Ministry of Training, Colleges and Universities. The curriculum for the Reinforcing Rodworker Apprenticeship (trade regulation 100/01 – trade code 452A) is available upon request from M.T.C.U. Ontario.

The Reinforcing Rodworker apprenticeship consists of 3640 hours of on the job training and 360 hours of In-school training to complete the apprenticeship.

Other courses also offered for Reinforcing Rodworker training in addition to the formal in-school apprenticeship are:

- Generic Health and Safety Level 1
- Fall Arrest Certification Training
- WHMIS
- First Aid/CPR
- Welding
- Rigging Safety Certification
- Power Elevated Work Platform
- Confined Space Training
- Fork Truck/Propane Handling
- Swing Stage Operator Certification
- Blueprint Reading
- Post-Tensioning Certification

Provincial Ironworkers Locals

Local 700 Windsor, London, Sarnia
Local 721 Toronto
Local 736 Hamilton
Local 759 Thunder Bay
Local 765 Ottawa
Local 786 Sudbury

Training Centres

Ironworkers Local 721
Training and Rehabilitation Centre
909 Kipling Ave.
Etobicoke, ON
416-232-9565 • cknowlton721@rogers.com

Ironworkers Local 700
R.R. #3, 4069 County Rd. #46
Maidstone, ON N0R 1K0
Tel: 519-737-7110 • Fax: 519-737-7113
www.ironworkerslocal700.com

Ironworkers Local 736
1955 Upper James St.
Hamilton, ON L9B 1K8
Tel: 905-679-6439 • Fax: 905-679-6617
www.iw736.com

Ironworkers Local 786
97 St. George St.
Sudbury, ON P3C 2W7
Tel: 705-674-6903 • Fax: 674-8827
www.iw786.com

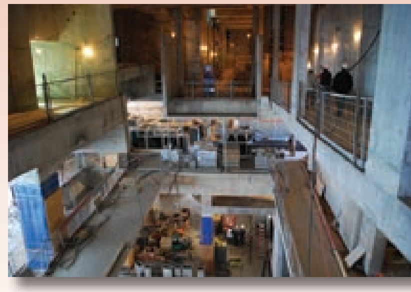
For further information please contact the Ontario Iron Workers District Council:

1434 Chemong Rd.
Unit 12 & 13
Selwyn, ON K9J 6X2
Tel: 705-748-3099
Fax: 705-748-3028
Email: odciw@bellnet.ca

Iron Workers
District Council of Ontario

MID TO HIGH RISE RESIDENTIAL AWARD 2012

Toronto International Film Festival



OWNER:
King and John Festival Corporation

ARCHITECT OF RECORD:
Kirkor Architects & Planners

DESIGN ARCHITECT:
Kuwabara Payne Mckenna Blumberg Architects

ENGINEER OF RECORD:
Jablonsky, Ast and Partners

GENERAL CONTRACTOR:
The Daniels Corporation

CONSTRUCTION MANAGER:
PCL Constructors Canada Inc.

FORMING CONTRACTOR:
C.I.P. Group

MATERIAL SUPPLIER:
Innocon

ADDITIONAL PARTICIPANTS:
- Aluma Systems Inc.
- Harris Rebar
- LIUNA Local 183
- National Concrete Accessories
- Toronto International Film Festival

Ontario Concrete Awards

2007 ONTARIO CONCRETE AWARD WINNING PROJECT FOR ARCHITECTURAL MERIT

ST. GABRIEL'S PASSIONIST CHURCH

The new church of St. Gabriel of the Sorrowful Virgin Roman Catholic Parish and the Passionist Community of Canada was designed to reflect the eco-theology of Father Thomas Berry, and his belief that we must all work to establish a mutually enhancing human-earth relationship. The structure makes effective use of glass and concrete components towards achieving both an aesthetic design and inspirational space for worship.

Concrete played the dual role of structural component and architectural element in this project. Designed by the collaborative efforts of both an artist and architect, this project makes ample use of exposed concrete surfaces. Concrete contributes significantly to the sense of grandeur and permanence appropriate for the groundbreaking worship space. While the entire south façade wall is glazed with clear glass, the 3 remaining walls exposed architectural concrete that serve as a constantly changing canvas for the dynamic play of natural light that filters through the coloured glass panels of the continuous perimeter skylight. This light is further fractured by wall-mounted dichroic coated reflectors, spilling into the midst of the congregation and across the concrete walls and floor.

The exposed concrete walls combined with the raised concrete access flooring provide the perfect acoustical environment for a church. The resonance enables the organ to sound like it is being played in an ancient stone cathedral.

St. Gabriel's church is distinctly different from most suburban churches that are corralled by huge asphalt parking lots. St. Gabriel's accommodates the majority of its parking spaces in a concrete underground structure. This unprecedented investment ensures that a large portion of the ground plane remains devoted to the "green-roof" garden.

Concrete was a logical choice for the superstructure because of the underground parking. The use of concrete contributed to achieving a number of LEED credits, such as the substitution of "slag" for a portion of the cement content and for the recycled content in the reinforcing steel used. Exposed throughout the building on floors, walls and ceilings, the architectural concrete structure saves precious natural and financial resources by eliminating the need for finishes such as drywall or paint. Composed of 11/2" thick concrete panels, the raised access floor in the nave (central open area of the church) and narthex (the entrance or lobby area) forms a plenum component of the displacement ventilation strategy. This approach helps to maximize energy efficiencies while providing a handsome, durable and practical finish underfoot.

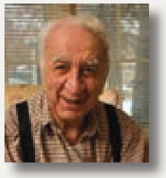
The thermal mass of the exposed concrete walls, together with the raised concrete access floor supplied by Haworth, serve as heat sinks that absorb the sun's energy and release it back into the worship space when the temperature cools. The thermal mass of the 350mm thick concrete walls combined with R-25 insulation on their exterior side also helps to retain heat during winter and reduce heat gain in the summer, thereby contributing to even greater energy savings.

Concrete is also used as an integral part of the exterior design of St. Gabriel's. An iconic roof scupper constructed of cast-in-place concrete spills rainwater from the narthex roof into a cast-in-place concrete water feature that highlights the need to conserve and protect water as the precious natural resource because of its use as a symbol of purification in the rite of Baptism.

A generously proportioned piazza designed to be used as a seasonal outdoor gathering space and staging area for weddings and funerals incorporates several series of precast pavers in a pattern inspired by the mid-century work of Bauhaus modern artists Josef and Anni Albers.

Owner:	Passionist Community of Canada
Architect:	Larkin Architect Limited
Engineer:	Carruthers & Wallace, *part of the Trow Group of Companies*
General Contractor:	Martin-Stewart Contracting Ltd.
Material Supplier:	St Marys CBM
Additional Participants:	• Aldershot Landscape Contractor Limited • Aluma Systems Inc. • Camino Modular Systems Inc. • Carpenters Local 27 • David Pearl • Enermodal Engineering Limited • Haworth Ltd. • Ian Gray and Associates • Ironworkers Local 721 • LIUNA Local 506 • National Concrete Accessories • Ronco Steel Centre Limited • Salit Steel • Structform International • UCC Group • Unilock • Weissbau Inc.

Incorporating these and other sustainable design strategies contributes to an understanding of early scriptural teachings that emphasized the sacredness of all creation and not just the sacredness of human kind. The new building as a sacred space presents a "Gestalt whole", and, like the medieval cathedrals of Europe, becomes itself a form of Catechesis, engaging the senses and inviting transformation.



In Memory of Sam Manna from the Concrete Formwork Association of Ontario. His passion for this project was unsurpassed.

2011 ONTARIO CONCRETE AWARD WINNING PROJECT FOR MID TO HIGH RISE RESIDENTIAL

ABSOLUTE WORLD

The Absolute World is an iconic architectural innovation constructed by Dominus that has redefined downtown Mississauga. The 56 and 50 story landmark towers represent a major breakthrough in conventional tower design. Eschewing straight lines, fixed points and vertices, the tower is a curved and rotating form that is unlike anything seen before in Canada or the world. The objective was to provide Mississauga's "Four Corners" with an architectural landmark that redefined the area and its skyline.

The Absolute World is part of a master-planned community of five-towers. With over 1.7 million square feet, the Absolute community contains 1,850 residential units, a three-story 35,000 square foot recreation facility and retail facilities.

The Absolute World's creative architectural design resulted in a number of construction challenges and opportunities for innovation. The construction partners were not constrained by traditional approaches when addressing complex issues involving thermal transfer, forming, and concrete usage. Innovative construction solutions and engineering design were able to realize the vision and achieve results within budget and on schedule.

Forming

The unique design properties of the building also required an innovative concrete forming method that was both practical and safe. Traditional fly tables were not appropriate for this construction because they would have resulted in large unsupported panels when the rotation of the floor plate was more than two degrees. The formwork partner, Premform, was required to innovate a new forming method that would allow for configuration changes while maintaining structural integrity and without compromising safety.

Premform's solution teamed together two main features - an EFCO climbing elevator formwork system; and a modified Peri's SKYDECK drop head system with a modified rail climbing RCS system.

The EFCO climbing elevator formwork system contributed to project efficiency and allowed for faster turnaround on the main central core of the building. Schedule delays were avoided with this system.

The modified SKYDECK and RCS system represented an innovation for Peri as they had never before designed a system that was required to climb and also move in relation to a varying rotation. The modified SKYDECK provided the ability to form the constantly changing floor plate by allowing panels to be carried out immediately after the slab concrete reached the required strength. This revolving process permitted panels to be used immediately for the next cycle and created efficiencies.

Since the SKYDECK system is not traditionally used above grade, a specialized enclosure system was required around the formwork to ensure safety. Peri adopted a modified RCS system that worked in conjunction with the SKYDECK system. These modifications created a safe environment that also provided efficiency benefits. The enclosure simplified the heating requirements for the concrete slabs during winter pours as it enclosed two floors below the current deck being completed. The result was greater efficiency and less lost days due to weather constraints.

Through these innovations, Dominus was able to achieve a cycle time from floor to floor that could match those of traditional systems for conventional building designs.

Concrete

The last major innovation in the construction of this building related to the use of the concrete itself. Although the building was unique in its design, it was still required to meet all structural requirements for a residential condominium. This presented a number of unique challenges.

The concrete supplier, Innocon, had to identify a product that could meet Dominus' need for high volume; accurate consistency; accommodation of a tight construction schedule; reliability in a full cycle of seasons; and functional workability on floor slabs. Innocon recommended the use of their self-consolidating concrete Agilia. This product was capable of meeting all our requirements for the columns and walls and could be used in a special mix for the slabs. The product also offered the added benefit of increased efficiency by requiring fewer workers. The construction schedule spanned over a full cycle of seasons and special methods were utilized to ensure sufficient heating in the winter and cooling in the summer to allow the concrete to properly cure.

For the columns and walls the Agilia concrete performed exceptionally well. The specified mix designs called for an ultimate strength of 70 MPa in 90 days. Testing demonstrated that these levels were achieved in only 28 days.

The product's superior performance also required the concrete finishers to achieve greater efficiency and adapt to an accelerated schedule because the concrete reached a finished state more rapidly than traditionally expected.

In order to increase the benefit of using Agilia, Dominus opted for the use of concrete pumps to alleviate unnecessary crane usage and hoisted concrete with the traditional bucket method. For the columns, Premform prefabricated many of the column supports in a staging area and then hoisted them into place. These techniques contributed to speed and efficiency.

Summary

The Absolute World represents a visionary architectural design that required innovation and creative problem solving in its construction. Inventive approaches to managing thermal transfer; versatile formwork; a customized RCS system; and innovative concrete products, all contributed to building this vision. Working with its partners, Dominus met the construction challenges head-on with creative cost effective solutions and strong project management skills to keep the development on schedule and on budget from its inception. The Absolute World has changed the face of downtown Mississauga and has pushed the boundaries for innovation in design and construction.

Owner: Fernbrook - Cityzen

Architects: Burka Architects Inc.

Engineers: Sigmund Soudack & Associates Inc.

Construction Team Members:

General Contractor: *Dominus*
Forming Contractor: *Premform Limited*
Concrete Supplier: *Innocon*

Additional Participants:

- Aluma Systems Inc.
- Amherst Concrete Pumping
- Coffey Geotechnics
- EFCO Corp.
- Gilbert Steel Limited
- Ironworkers Local 721
- LIUNA 183
- Peri Formwork Systems Inc

Project Facts

- Completion Fall 2011
- Total cumulative floor plate rotation - 200 to 209
- 6 levels of underground parking – 954 spaces
- Concrete – 61,900 m^3
- Rebar – 9,210 tonnes
- Budget $180 Million
- Size: Building D – 56 stories, 427 suites, 179.5 m high
  Building E – 50 stories, 453 suites, 161.2 m high

ONTARIO CONSTRUCTION SECRETARIAT

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OCCDC

Ontario Cast-in-Place Concrete Development Council (OCCDC)
365 Brunel Road, Unit 3
Mississauga ON L4Z 1Z5
Phone: 905-507-1122
Fax: 905-890-8122
buildings@occdc.org

www.occdc.org

Revision 3.0

UFCW Locals 175 & 633 CANADA