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.

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.

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

- Providing educational seminars on reinforced concrete at the World of Concrete Pavilion and the Canadian Concrete Expo

- Providing educational seminars to Ontario University programs in Architecture and Engineering

PARTNERSHIPS

The OCCDC works closely with allied groups such as:

- Cement Association of Canada

- Ontario General Contractors Association

- Concrete Floor Contractors Association of Ontario

The OCCDC's core members directly fund the organization and all members volunteer time and other resources to complete specific projects.

OCCDC

Ontario Cast-in-Place Concrete Development Council (OCCDC)

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www.occdc.org

OCCDC CORE MEMBERS

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.

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

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. iw721.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

CONCRETE ONTARIO, formerly 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.concreteontario.org

REINFORCING STEEL INSTITUTE OF CANADA 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

The **CONCRETE FORMING ASSOCIATION OF ONTARIO** (CFAO) was established in 1971 and 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.

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

MID TO HIGH RISE RESIDENTIAL CAST-IN-PLACE SUSTAINABLE CONCRETE CONSTRUCTION

RIVER CITY - PHASE 3

River City Phase 3 is the third phase of a 1200-unit residential development by Urban Capital in the west Donlands neighborhood. It boasts 149 residential vehicle parking spaces, one electric charging station, 18 visitor spots and 4-car share locations.

Location	Toronto, Ontario
Start Date	October/2015
Completion Date	October/2018
Contract Value	$68,000,000
Foot Plate	3000m²
Total Concrete	17,700m³

Owner	Urban Capital
Architect of Record	Saucier+Perrotte Architectes / Zas Architects
Engineer of Record	RJC Engineers
General Contractor	Bluescape Construction Management
Forming Contractor	Avenue Building Corporation
Material Supplier	St Marys CBM

Additional Participants
- Aluma Systems Inc.
- BASF Canada Inc.
- Carpenters Union Local 2
- Ironworkers Local 721
- IUOE Local 793
- LiUNA Local 183

THE ADVANTAGES OF REINFORCED CONCRETE BUILDING FRAMING SYSTEMS

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.

THE Power of Concrete

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

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 accommodated 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.

ARCHITECTURAL MERIT CAST-IN-PLACE
TTC PIONEER VILLAGE SUBWAY STATION

Pioneer Village Station is a brand-new transit hub straddling the northern border of Toronto. This project forms part of Toronto Transit Commission's (TTC) $3.2 billion, 8.6km subway extension called the Toronto York Spadina Subway Extension (TYSSE).

Project Credits	
Owner	Toronto Transit Commission
Architect of Record	IBI Group
Engineer of Record	WSP Canada Inc.
General Contractor	Walsh Canada
Forming Contractor	Limen Structures
Material Supplier	St Marys CBM

Project Details	
Location	Vaughan, Ontario
Contract Type	Lump Sum
Project Type	Transit
Construction Value	$223,825,706 M
Start Date	October 1, 2011
Completion Date	June 15, 2017

Additional Participants
- AGC Glass
- Alsop Architects
- BASF Canada
- Benson Steel Ltd.
- Bird Mechanical Ltd.
- Carpenters Union Local 27
- Core Metal Inc.
- Deep Foundations
- FCFP
- Harris Rebar
- HH Angus
- Ironworkers Local 721
- LEA Consulting
- LiUNA Local 506
- Plan Group
- Richard Stevens Architects
- Ritz Architectural System
- The Spadina Group Associates

2018 Ontario Concrete Awards

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 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 DIM
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.

KEY TERMS

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

EMBEDMENT LENGTH
The length of embedded reinforcement provided beyond a critical section.

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

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

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

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

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

CONCRETE CONSIDERATIONS

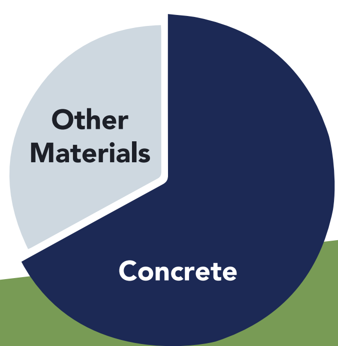
Use high strength concrete in columns
The high strength may reduce the column size or the amount of reinforcing steel required for the column. High strength concrete may also allow for the use of one standard column size throughout the structure.

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.



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 COMBINED.

Source: Cement Association of Canada

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.

OCCDC

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.

REINFORCING STEEL INSTITUTE OF CANADA

One of the objectives of the Members of the Reinforcing Steel Institute of Canada 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.

NONPROFIT ORGANIZATION

The RSIC 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 RSIC 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 RSIC for more information.

THE ELEMENTS OF REINFORCING STEEL

Order your copy of “The Elements of Reinforcing Steel” manual today and learn about:

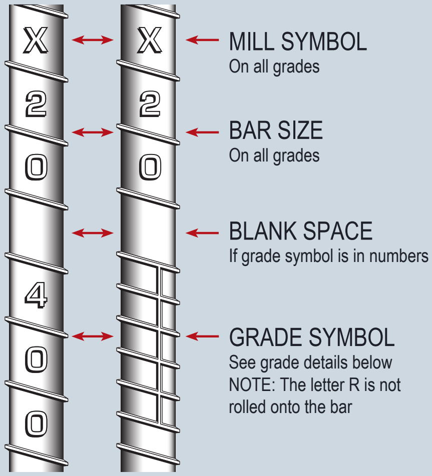
- Architectural/Engineering Information
- Material Standards and Specifications
- Standard Quotation Components
- Standard Practices for Estimating and Detailing
- Fabrication Standards
- Standards for Placing and Bar Supports
- Reinforcing Steel in Corrosive Environments
- Requirements for Splicing
- Welded Wire Fabric Standards
- Standards for Post-Tensioning
- Appendix and Tables

IDENTIFICATION REQUIREMENTS

Deformed Concrete Reinforcing Bar comply with CSA Standard G30.18 -09 R19

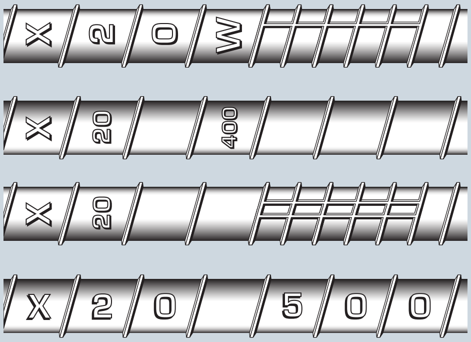
Identification markings occur at intervals of 1 to 1.5 metres along the bars.

SEQUENCE



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.
GRADES 400W 500W	The letter W between the blank space and the grade symbol or in the blank space.

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 on markings occur at intervals of 1.0 to 1.5 meters along the Bar. If from Rod Coils markings could be at 0.5 meter intervals.

TYPICAL IDENTIFICATION PATTERNS OF PRODUCERS SUPPLYING THE CANADIAN MARKET

ALTASTEEL LTD.

ARCELORMITTAL Long Products Canada
Longueuil Mill

ARCELORMITTAL Long Products Canada
Contrecoeur West

ARCELORMITTAL Long Products Canada
Contrecoeur East

GERDAU
Cambridge Mill

GERDAU
Manitoba Mill

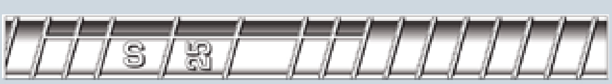
GERDAU
Sayreville Mill

GERDAU
Whitby Mill

MAX AICHER - North America LTD.
(MANA)

NORTH AMERICA
STAINLESS

NUCOR AUBURN NY



NUCOR STEEL
SEATTLE INC.

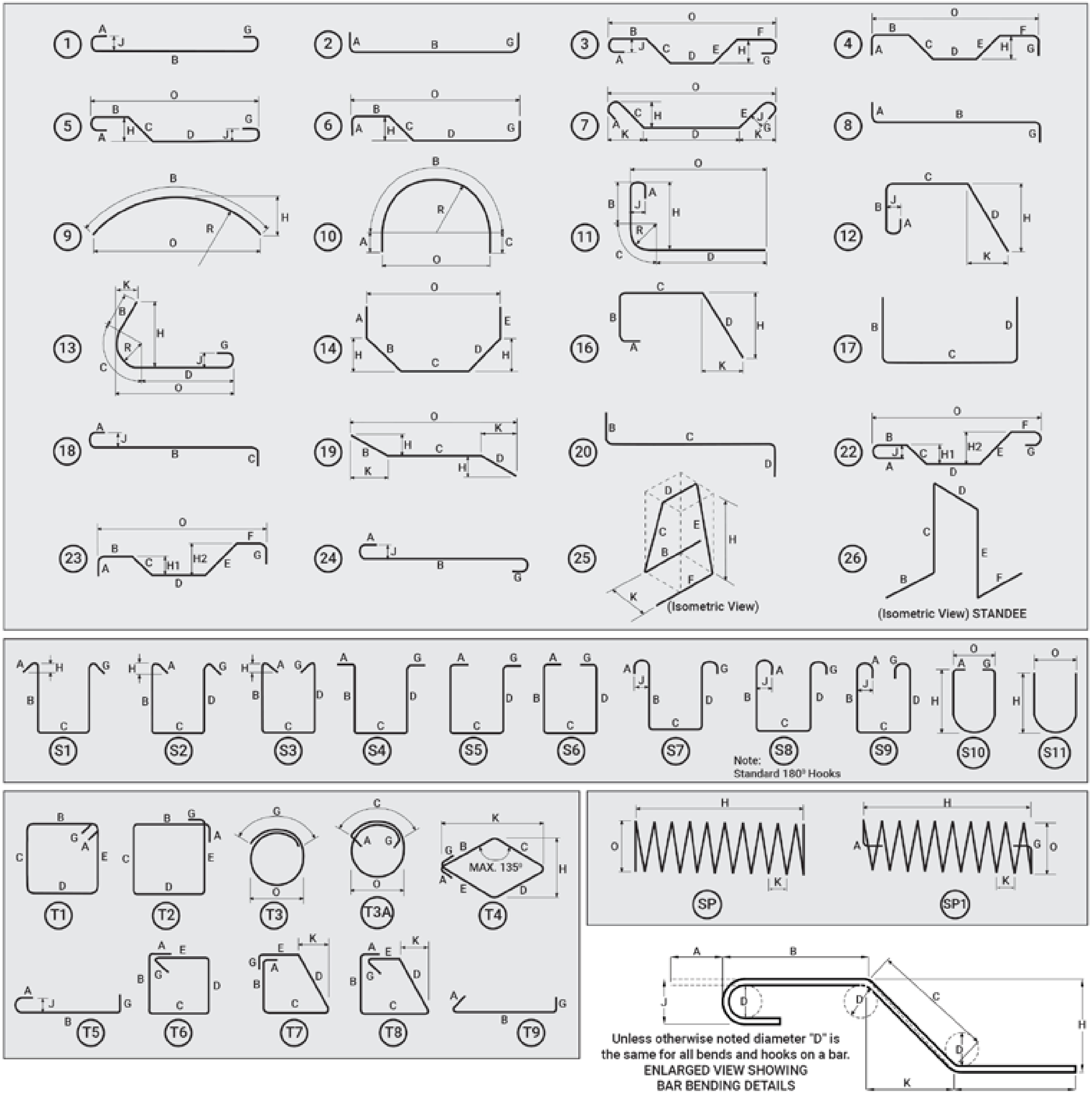
VALBRUNA
CANADA LTD.

Reinforcing Steel Institute of Canada (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.

rsic@rebar.org | 416-239-7746 | rebar.org

RSIC IAAC

TYPICAL BAR BENDS



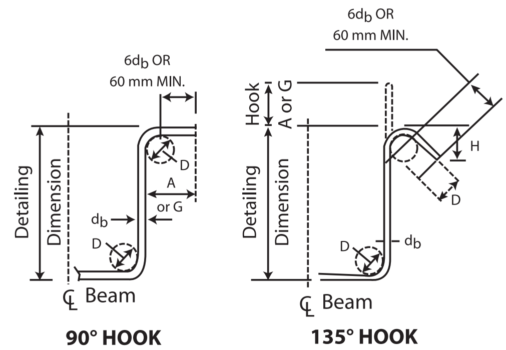
NOTES:

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. Type T3 "G" dimensions are equal to Class B splice.
7. Type T3A Lap "C" shall be minimum 150mm or distance to hook ties around two adjacent longitudinal bars whichever is greater.
8. Figures shown in circles show types.
9. All bar bends other than the types shown above must be designated as type "X".
10. Spirals SP1- A and G shall be at least $24d_b$ (CSA S6-14 CL 8.14.4.2)

HOOK DIMENSIONS

STIRRUP AND TIE HOOK DIMENSIONS



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

TABLE 5A.

STANDARD HOOK DIMENSIONS FOR BLACK/STAINLESS STEEL REINFORCING

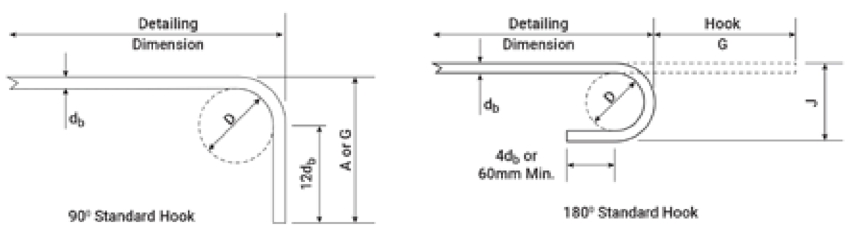
BAR SIZE	BAR DIAM.	400R or 500R				400W or 500W			
				90° HOOK	180° HOOK			90° HOOK	180° HOOK
	d_b(mm)	D (mm)	J (mm)	A or G* (mm)	A or G (mm)	D (mm)	J (mm)	A or G* (mm)	A or G* (mm)
10M	11.3	70	90	180	140	60	80	180	130
15M	16.0	100	130	260	180	90	120	250	170
20M	19.5	120	160	310	220	100	140	300	200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

- The dimensions provided use the minimum bend diameters (D) permitted in (CSA A23.1-14 CL.6.6.2.3 and Table 16).
- Standard hooks are defined in (CSA A23.1-14 CL.6.6.2.4).
- To achieve "J" dimension the pin diameter is less than the standard pin diameter.
- Bend diameter shall not be reduced by more than 10% from those listed unless specified by the Engineer and/or Owners Representative.

* Add the additional hook dimension G to the detailing dimension to estimate the total bar length.

For 180° hooks: $G = (4d_b \geq 60\text{ mm}) + \pi (D+d_b)/2 - D/2 - d_b$

For 90° hooks: $G = A = 12d_b + D/2 + d_b$



REINFORCING STEEL BARS

BAR DESIGNATION NUMBER (BAR SIZE)	MASS kg/m	NOMINAL DIMENSIONS		
		DIAM. 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.

CONCRETE FACT:

THE TOTAL PRODUCTION OF READY MIXED CONCRETE IN ONTARIO FOR 2019 WAS APPROXIMATELY 10.0 MILLION CUBIC METRES.

Source: Concrete Ontario

2019 Ontario Concrete Awards

INFRASTRUCTURE
GUILDWOOD STATION

Guildwood Station, a simple linear composition comprised of a station building, utility building, plazas and tunnel access pavilions, is located on a narrow interstitial space between an existing parking lot and bermed rail corridor on the north side of the property.

Location	Toronto, Ontario
Construction Cost	$62,000,000
Construction Start	January 2016
Official Opening	June 19, 2019
Structural Formwork	14,100 m2
Concrete Placed	5,374 m3
Precast Pedestrian Tunnels	Total 33.8 linear metres
Caissons Installed	330+
Precast Curbs Installed	2,150

Owner	Metrolinx
Architect of Record	RDHA
Engineer of Record	WSP
General Contractor	Kenaidan Contracting Ltd.
Material Supplier	Ontario Redimix, A division of CRH Canada Group Inc.
	Pre-Con

Additional Participants
- BASF Canada Inc.
- Elias +, Landscape Architect
- Euclid Chemical
- Gilbert Steel Limited
- Ironworkers Local 721

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.

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

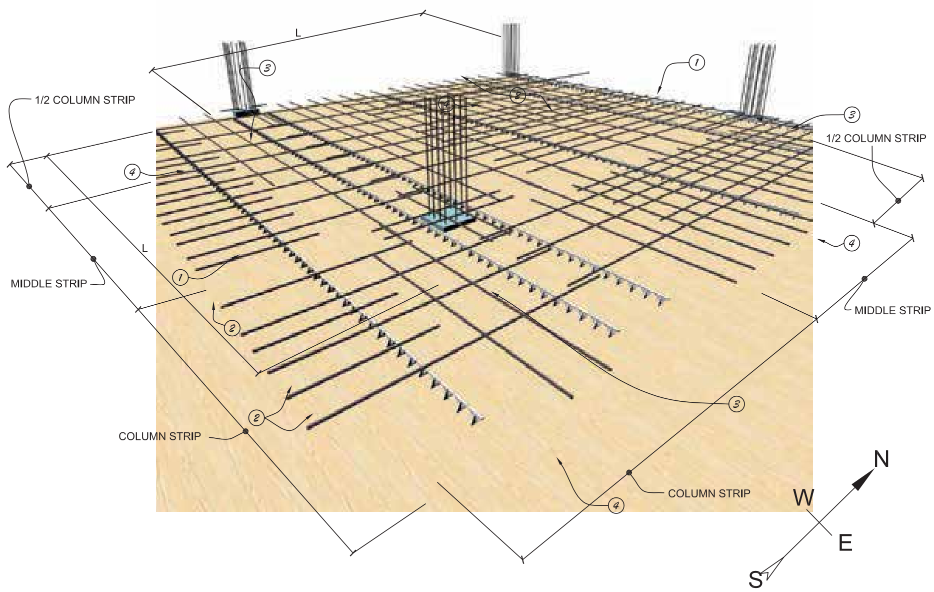
The use of bar supports should follow the industry practices presented in Chapter 8 of RSIC Manual of Standard Practice. Placing reinforcement on layers of fresh concrete as the work progresses and adjusting the bars during the placing of concrete should not be permitted. Bar supports may be made of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

FABRICATION OF REINFORCING BAR

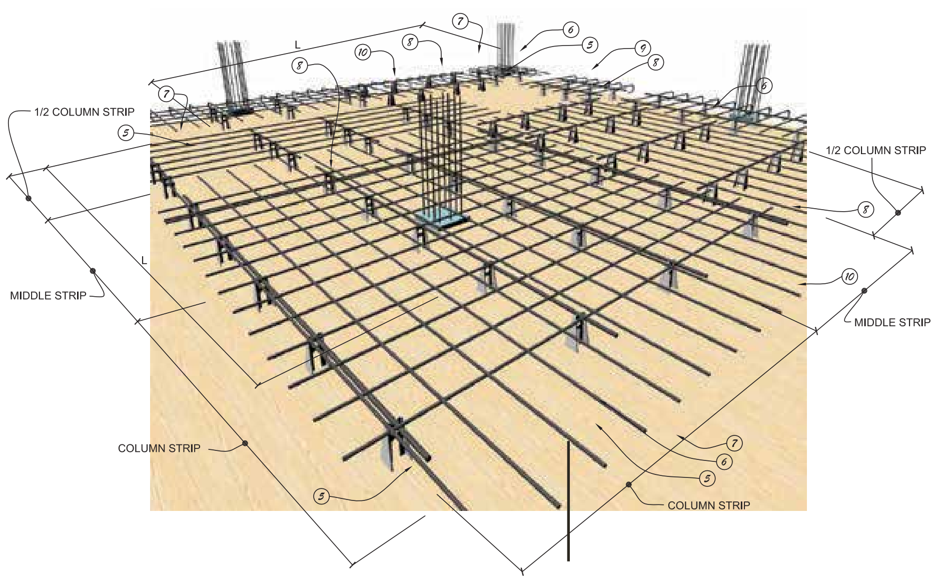
Fabrication consists of the cutting, identification of bars, bundling, bending and loading for transport, reinforcing steel to a specified bar list. *It is recommended that all rein- forcing bars be shop fabricated, since fabrication operations can be performed with greater accuracy in the fabricating shop.*

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

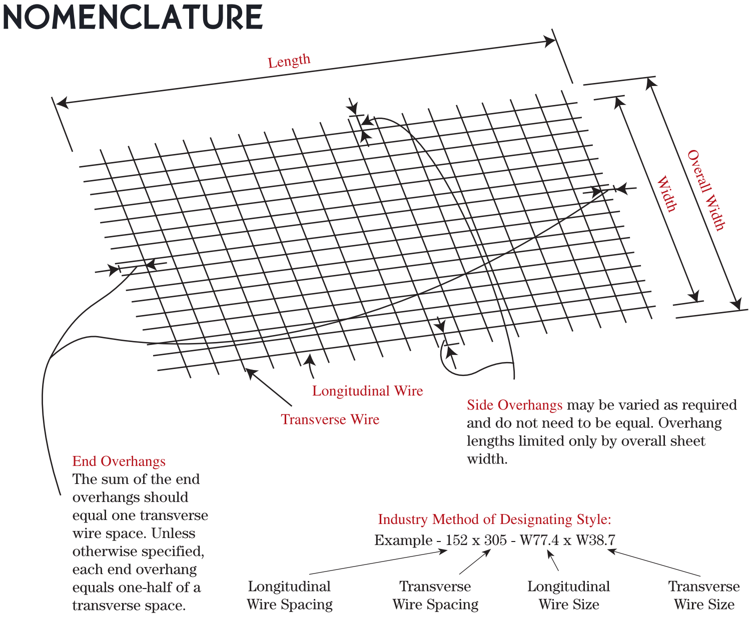


MILLIMETERS OF LAP RELATED TO NUMBER OF BAR DIAMETERS									
BAR SIZE	BAR DIAM	NUMBER OF BAR DIAMETERS (Using Bar Size)							
		12	20	24	30	36	40	48	54
10M	11.3	120	200	240	300	360	400	480	540
15M	16.0	180	300	360	450	540	600	720	810
20M	19.5	240	400	480	600	720	800	960	1080
25M	25.2	300	500	600	750	900	1000	1200	1350
30M	29.9	360	600	720	900	1080	1200	1440	1620
35M	35.7	420	700	840	1050	1260	1400	1680	1890
45M	43.7	LAP NOT PERMITTED							
55M	56.4	LAP NOT PERMITTED							

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	

*Upon Request   ***Also available in Galvanized sheet 8X20   Available in Grades Fy 485Mpa, 550Mpa
For Roll availability- check with local suppliers

NOMENCLATURE



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

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)

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.

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 and Compression or Compression only. There are three methods of splicing:

- Lapped
- Mechanical
- Welded

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

Welded Construction and Standard Mesh specifications in Canada and USA as per ASTM A1064/A1064M-17,

*Standard "Specifications for Carbon Steel Wire and Welded Wire Reinforcement, Plain and Deformed for Concrete"

REINFORCEMENT 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, GFRP, 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, GFRP 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.

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 CSA specification requirements. RSIC publishes detailed guidance on this subject available on RSIC's Manual of Standard Practice.

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.

ONTARIO FORMWORK ASSOCIATION

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

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.

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.

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."

ONTARIO FORMWORK ASSOCIATION

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

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.

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

MEMBERS OF THE OFA

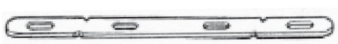
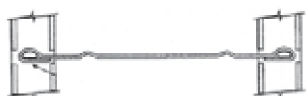
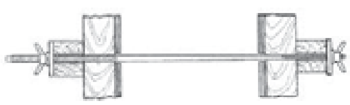
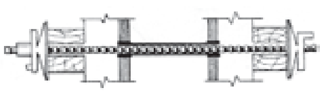
Avenue Building Corporation
Delgant Construction Ltd
Dominion Forming Inc.
Hardwall Construction
Hardcastel Group
Italform Limited
J.M.S. Forming Ltd
Paramount Structures Ltd
Premform Ltd
Resform Construction Ltd
Straw Construction Group
Summit Forming
T.F. Construction Ltd
Verdi Inc.
Yukon Construction Inc.

FORMWORK FOR CONCRETE

CONCRETE FACT: CONCRETE IS SECOND ONLY TO WATER AS THE MOST CONSUMED SUBSTANCE IN THE WORLD.

Source: Globe & Mail

ONE-PIECE TIES

ONE-PIECE TIES		SAFE LOADS	
FLAT TIE		1500, 2250, and 3000 lb	Used to secure and space modular panel forms. Available in several configurations. Notched for breakback.
LOOP TIE		2250 and 3000 lb	Secures and spaces prefabricated modular forms. Notched for a 1” breakback. Crimp is antiturn feature.
SNAP TIE WITH SPREADER WASHERS		2250 and 3350 lb	Used for job-built forms, lighter construction. May have cone spreader and waterseal washer. Notched for a 1” breakback.
FIBERGLASS TIE		3000, 7500, and 25,000 lb	Long lengths supplied for cutting as desired on the job. Custom colors available. Cut off flush with surface of hardened concrete.
TAPER TIE		7500 to 50,000 LB	Used where specs require or permit complete removal of tie from concrete. Tie is reusable.
THREADED BAR WITH UNATTACHED SLEEVE		10,000 to 32,500 lb	Standard 20-ft lengths cut to meet project require-ments. Double nuts may be needed for higher load capacities. Bar is reusable

INTERNALLY DISCONNECTING TIES

SHE-BOLT TIE		4900 to 64,000 lb up to 155,000 in high strength steel	Heavy duty, with reusable end bolts. No internal spreader, but external spreader bracket available.
TWO-STRUT COIL TIE WITH CONES		Two-strut, 3000 to 13,500 lb; Four-strut, 9000 to 27,000 lb	Designed for medium to heavy construction. With or without cone spreaders. Bolts reusable.

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 pic-tured. 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.

CONCRETE FORMWORK ASSOCIATION OF ONTARIO

Established in 1971, the Concrete Formwork Association of Ontario (CFAO) 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; on the Carpenters' and Labourers' Employer Bargaining Agencies in negotiating Provincial collective agreements, to establish wages, etc., that apply to our sector.

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

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.

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 A23.1:19 – Concrete materials and methods of concrete construction, Tables 1 – 4 outline the minimum durability requirements.

TABLE 1
DEFINITIONS OF C, F, N, A, S & R CLASSES OF EXPOSURE

(See Clauses 3, 4.1.1.1.1, 4.1.1.1.3, 4.1.1.5, 4.1.1.8.1, 4.1.2.3, 6.1.4, 6.6.7.6.1, 7.1.2.1, 9.1, L.3, and R.1, Tables 2, 3, and 17, and Annex L.)

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 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 structures exposed to seawater located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.

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 structures exposed to seawater. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.

C-4 Non-structurally reinforces 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.

N Concrete that when in service is neither exposed to chlorides nor to freezing and thawing nor to sulphates, either in a wet or dry environment.
Examples: footings, walls and columns.

N-CF Interior concrete floors with a steel-trowel finish that are not exposed to chlorides, nor to sulphates either in a wet or dry environment.
Examples: interior floors, surface covered applications (carpet, vinyl tile) and surface exposed applications (with or without floor hardener), ice-hockey rinks, freezer warehouse floors.

A-XL 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 might be generated, with higher durability performance expectations than A-1 class.

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 might be generated.
Examples: reinforced beams, slabs, and columns over manure pits and silos, canals, and pig slats; and 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 bunders, and 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., forcemains); 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 exposures (Table 2 and 3).

S-2 Concrete subjected to severe sulphate exposure (Table 2 and 3).

S-3 Concrete subjected to moderate sulphate exposure and to seawater or seawater spray (Table 2 and 3).

R-1 Residential concrete for footings for walls, columns, fireplaces and chimneys.

R-2 Residential concrete for foundation walls, grade beams, piers, etc.

R-3 Residential concrete for interior slabs on ground not exposed to freezing and thawing or deicing salts.

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) All classes of concrete exposed to sulphates shall comply with the minimum requirements of S class noted in Tables 2 and 3. In particular, Classes A-1 to A-4 and A-XL in municipal sewage elements could be subjected to sulphate exposure.

5) No hydraulic cement concrete will be entirely resistant in severe acid exposures. The resistance of hydraulic cement concrete in such exposures is largely dependent on its resistance to penetration of fluids.

6) Decision of exposure class should be based upon the service conditions of the structure or structural element, and not upon the conditions during construction.

Source: Table 1, CSA A23.1:19/CSA A23.2:19 Concrete materials and methods of concrete construction/Test methods and standard practices for concrete.

TABLE 2 | CSA A23.1
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.)

			Air Content category as per Table 4[d]		Curing type (see Table 19)			
Class of exposure[a]	Maximum water-to-cementitious materials ratio[b]	Minimum specified compressive strength (MPa) and age (d) at test[b,i]	Exposed to cycles of freeze/thaw	Not Exposed to cycles of freeze/thaw	Normal concrete	HVSCMN-1	HVSCM-2	Chloride ion penetrability requirements and age at test[c]
C-XL or A-XL	0.40	50 within 56 d	1	e	3	3	3	< 1000 coulombs within 91 d
C-1 or A-1	0.40	35 within 56 d	1	e	2	3	2	< 1500 coulombs within 91 d
C-2	0.45[h]	32 at 28 d	1	n/a	2	2	2	--
C-3	0.50	30 at 28 d	n/a	e	1	2	2	--
C-4[e]	0.55	25 at 28 d	n/a	e	1	2	2	--
A-2	0.50	32 at 28 d	1	e	2	2	2	--
A-3	0.50	30 at 28 d	2	e	1	2	2	--
A-4	0.45	25 at 28 d	2	e	1	2	2	--
F-1	0.50[j]	30 at 28 d	1	n/a	2	3	2	--
F-2 or R-1 or R-2	0.55[j]	25 at 28 d	2[f]	n/a	1	2	2	--
N	As per the mix design for the strength required	For structural design	n/a	e	1	2	2	--
N-CF[g] or R-3	0.55	25 at 28 d	n/a	e	1	2	2	--
S-1	0.40	35 within 56 d	1	e	2	3	2	--
S-2	0.45[j]	32 within 56 d	1	e	2	3	2	--
S-3	0.50[j]	30 within 56 d	1	e	1	2	2	--

NOTES:

[a] See Table 1 for a description of classes of exposure.

[b] The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementitious materials ratio provided that freezing and thawing and de-icer scaling resistance have been demonstrated to be satisfactory. The water-to-cementitious materials ratio shall not be exceeded for a given class of exposure.

[c] In accordance with CSA A23.2-23C, an age different from that indicated may be specified by the owner. Accelerated moist curing in accordance with CSA A23.2-23C may be specified by the owner; in such cases, the age at test shall be 28 d. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, without calcium nitrite, shall be qualified to meet the requirements for the permeability index in this Table. For field testing, the owner shall specify the type of specimen and location from which it is taken. If cores are required, the concrete cores shall be taken in accordance with CSA A23.2-23C.

[d] Air entrained concrete shall not receive a steel trowelled finish. See Note 4) to Clauses 7.7.4.3.1 and 7.7.4.3.2.

[e] Class N-CF concrete shall not contain an air entraining admixture. Other classes of concrete falling in this air content category have no requirement to provide entrained air however the producer may choose to add entrained air in order to modify plastic concrete properties such as bleeding, workability, cohesiveness, etc. No air entrainment shall be added to concrete which is to receive a steel trowel finish.

[f] Air entrainment shall be waived for F-2 class exposures frozen in an air dry condition and receiving very limited cycles of freeze/thaw. Interior ice rink slabs brought to sub-zero levels before the introduction of water and dry freezer slabs have been found to perform satisfactorily without entrained air when steel trowelled.

[g] See Clause 7.1.2 for concrete mixes for concrete floors.

[h] The maximum water-to-cementitious material ratio for HVSCM-1 concrete in a C-2 exposure shall not exceed 0.40.

[i] A different age at test may be specified by the owner to meet structural or other requirements.

[j] For reinforced concrete surfaces exposed to air and not directly exposed to precipitation, with depths of cover less than 50 mm, the water-to-cementitious materials ratio shall be not greater than 0.40 for HVSCM-1 concrete and not greater than 0.45 for HVSCM-2 concrete. This requirement is intended to minimize the risk of corrosion of embedded steel due to carbonation of the concrete cover. The exposure conditions that present the greatest risk are the soffits of suspended slabs and balconies and exposed vertical surfaces that receive little direct precipitation. For concrete that is continuously moist, the process of carbonation will be very slow.

TABLE 3
ADDITIONAL REQUIREMENTS FOR CONCRETE SUBJECTED TO SULPHATE ATTACK[1]

(See Clauses 4.1.1.1.1, 4.1.1.6.2, 4.1.1.6.3, and L.3 and Tables 1, 7, 24, and 25.)

						Performance requirements[4, 6] Maximum expansion when tested using CSA A3004-C8, %	
Class of exposure[a]	Degree of exposure	Water-soluble sulphate (SO4)† in soil sample, [2] %	Sulphate (SO4) in groundwater sample, [3] mg/L	Water soluble sulphate (SO4) in recycled aggregate sample, %	Cementitious materials to be used[4]	At 6 months	At 12 months[7]
S-1	Very severe	> 2.0	> 10,000	> 2.0	HS[5],HSb, HSLb, or HSe	0.05	0.10
S-2	Severe	0.20 – 2.0	1500 – 10,000	0.60 – 2.0	HS[5], HSb, HSLb, or HSe	0.05	0.10
S-3	Moderate (including seawater exposure[1])	0.10 – 0.20	150 – 1500	0.20 – 0.60	MS, MSb, MSe, MSLb, LH, LHb, HS[5], HSb, HSLb, or HSe	0.10	

[1] For sea water exposure, also see Clause 4.1.1.5.
[2] In accordance with CSA A23.2-3B.
[3] In accordance with CSA A23.2-2B.

[4] Where combinations of supplementary cementitious materials and Portland, Portland-limestone, or blended hydraulic cements are to be used in the concrete mix design instead of the cementitious materials listed, and provided they meet the performance requirements demonstrating equivalent performance against sulphate exposure, they shall be designated as MS equivalent (MSe) or HS equivalent (HSe) in the relevant sulphate exposures (see Clauses 4.1.1.6.2, 4.2.1.1, and 4.2.1.3, and 4.2.1.4).

[5] Type HS cement shall not be used in reinforced concrete exposed to both chlorides and sulphates, including seawater. See Clause 4.1.1.6.3.

[6] For demonstrating equivalent performance, use the testing frequency in Table 1 of CSA A3004-A1 and see the applicable notes to Table A3 in CSA A3001 with regard to re-establishing compliance if the composition of the cementitious materials used to establish compliance changes.

[7] If the expansion is greater than 0.05% at 6 months but less than 0.10% at 1 year, the cementitious materials combination under test shall be considered to have passed.

Note: Limestone fillers shall not be used in concrete for any S class exposure listed in Tables 1 to 3. Portland-limestone cement shall not be used as the sole cementitious material in concrete for any S class exposure listed in Tables 1 to 3. However, blended hydraulic cements, or combinations of Portland-limestone cement and the minimum levels of supplementary cementitious materials listed in Table 9 of CSA A3001 and also meeting the test requirements of Table 5 in CSA A3001, may be used in any S class exposure listed in Tables 1 to 3.

TABLE 4
REQUIREMENTS FOR AIR CONTENT CATEGORIES

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.3.1, and 4.3.3.2, and Table 2.)

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

* 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 can be significantly lower than those measured at the end of the chute.

COLD WEATHER CONCRETING

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. As per CSA A23.1, cold weather concreting conditions are defined as:

• When the air temperature is 5°C or lower.

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

GENERAL PROCEDURES FOR COLD WEATHER CONCRETING INCLUDE:

• Removing all ice and snow from the subgrade or formwork.

• Ensuring that all materials and equipment needed for adequate protection and curing are on hand before the concrete placement.

• Protection equipment shall include heated enclosures, coverings, insulation or a suitable combination of these methods.

• Supplying the necessary supplemental heat required to ensure that forms, subgrades, and reinforcing steel is maintained at a minimum temperature of 10°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 as is defined by CSA A23.1 Tables 2 & 19.

• 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, which is caused by large temperature differences between the surface and the interior of the concrete, must be considered when the heating supplied during the curing period is going to be suspended. Protection shall not be removed until the temperature differential indicated in CSA A23.1 Table 20 has been achieved.

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.

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.

COLD WEATHER TABLES

TABLE 19 | CSA A23.1:19 ALLOWABLE CURING REGIMES

(see Clause 4.1.1.1.1, 7.7.1, 7.7.2.1, 7.8.9, 8.12.2, and Table 2)

Curing Type	Name	Description
1	Basic curing	3 d at ≥ 10 °C or for the time necessary to attain 40% of the specified strength.
2	Additional curing*	7 d total at ≥ 10 °C and for the time necessary to attain 70% of the specified strength.
3	Extended wet curing	A wet-curing period of 7 d at ≥ 10 °C and for the time necessary to attain 70% of the specified strength. The curing types allowed are ponding, continuous sprinkling, absorptive mat, or fabric kept continuously wet.

* When using silica fume concrete, additional curing procedures shall be used. See Clause 1.3.13.

TABLE 20 | CSA A23.1:19

Maximum permissible temperature differential between concrete surface and ambient to minimize cracking - wind up to 25 km/h (see Clauses 7.1.2.5 and 7.5.3 and Figure D.2.)

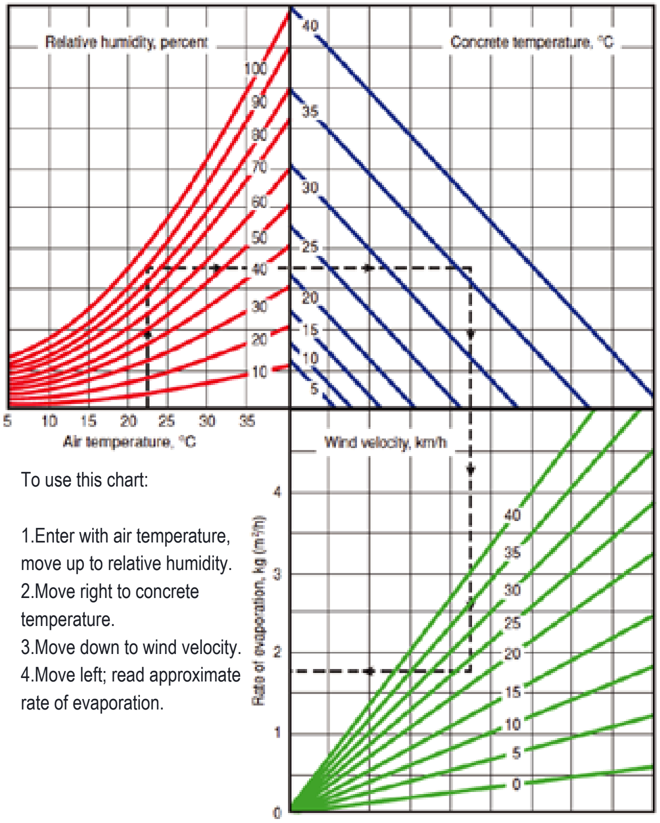
	Maximum permissible temperature differential, °C				
	Length to height ratio of structural elements *				
Thickness of Concrete, m	0 †	3	5	7	20 OR MORE
< 0.3	29	22	19	17	12
0.6	22	18	16	15	12
0.9	18	16	15	14	12
1.2	17	15	14	13	12
> 1.5	16	14	13	13	12

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

Notes:
(1) Curing of plant production of precast concrete shall be as set out in CSA A23.4.
(2) Concrete should be allowed to air-dry for a period of at least one month after the end of the curing period, before exposure to de-icing chemicals.
(3) The rate of compressive strength gain in concrete is significantly reduced below 10°C.

HOT WEATHER TABLES

FIGURE 1 ESTIMATION OF RATE OF EVAPORATION OF MOISTURE FROM A CONCRETE SURFACE



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 approximate rate of evaporation.

Note: Adapted (with metric values) from PCA EB101.05T. Additional information can be obtained from Berhane, 1984, and discussions of this article in ACI Materials Journal 82 (1985). Futher information and background can be obtained from Uno, 1998.

HOT WEATHER CONCRETING

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 (≥ 27°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
- Need for early curing.

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

During hot weather conditions where plastic shrinkage cracking may be an issue, ACI 305R recommends that the subgrade should be prewetted 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.

TEMPERATURE CONTROL

To minimize concrete temperatures, concrete placements should be scheduled during cooler periods of the day (I.e. early morning or night) to limit the exposure to the elements. To help control concrete temperatures, the ready-mix supplier can use a combination of the following tactics:

- Spraying aggregate piles with water
- Cooling the mix water
- Use of ice or liquid nitrogen
- Increased use of SCMs
- Use of chemical admixtures

The maximum concrete temperature at delivery shall be according to CSA A23.1:19 Table 14.

SLUMP

A concrete 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 larger 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

CURING

Curing shall begin immediately following the placing and finishing operations and the concrete shall be cured for the duration outlined in CSA A23.1:19 Tables 2 and 19 for the identified class of exposure.

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.

TABLE 14

Permissible concrete temperatures at placing

(See Clauses 5.2.5.4.1, 7.2.2.1, 7.5.1.3, 7.6.3.2.3, and 8.5.5)

	Temperatures, °C	
Thickness of section, m	Minimum	Maximum
< 0.3	10	32
≥ 0.3 - < 1	10	30
≥ 1 - < 2	5	25
≥ 2	5	20

Source:
1. Annex D Figure D.1 & Table 14, CSA A23.1:19/CSA A23.2:19 Concrete materials and methods of concrete construction/Test methods and standard practices for concrete. © 2019 Canadian Standards Association
2. ACI 305R-10 Guide to Hot Weather Concreting, American Concrete Institute 3. ACI 305.1M-14 Specification for Hot Weather Concreting, American Concrete Institute

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.

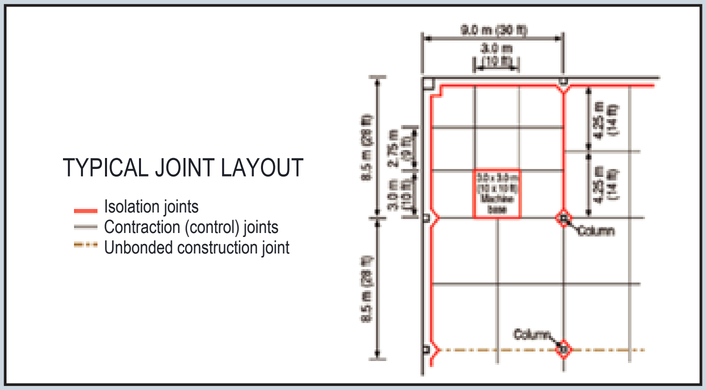
THE BASIC JOINTING SYSTEMS ARE AS FOLLOWS:

Isolation Joints: Joints that permit both horizontal and vertical movement between the slab and the adjacent concrete (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.

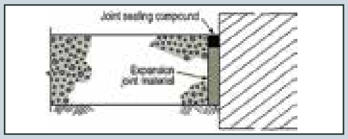
Contraction Joints: Joints that permit horizontal movement of the slab and induce controlled cracking at preselected locations (diagram 2). These joints are typically created by grooving the concrete while it is still in the plastic state or cutting the concrete in its hardened state once it has obtained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

Construction Joints: Joints that are stopping places in the process of construction (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).

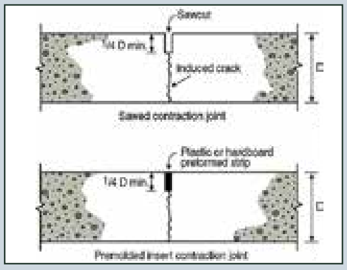
Proper jointing layout is performed before the concrete is placed by utilizing the basic rules above to determine the maximum joint spacing and then reviewing the plan view of the project to determine the proper locations of the three basic jointing types (see below). Concrete placement should never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



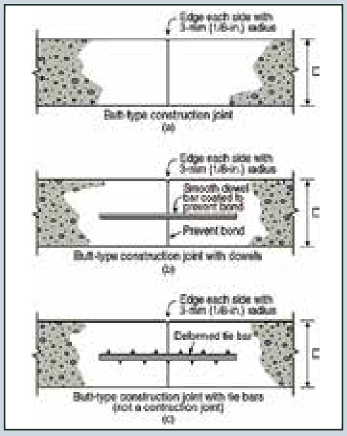
ISOLATION JOINT – DIAGRAM 1



CONTRACTION JOINT – DIAGRAM 2



CONSTRUCTION JOINT – DIAGRAM 3



References:
1 CSA A23.1-19 – 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

CURING CONCRETE

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 - Table 19) 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 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

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 manufacturer’s 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 affect 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 and stays in place 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
- Water curing should start without causing damage to the slab immediately after finishing.
- 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.

TABLE 19 | CSA A23.1:19

Allowable curing regimes

(See Clause 4.1.1.1.1, 7.1.2.2, 7.8.1, 7.8.2.1, 7.9.9, and Table 2)

BASIC CURING
3 d at ≥ 10°C or for the time necessary to attain 40% of the specified strength.

ADDITIONAL CURING*
7 d total at ≥ 10°C and for the time necessary to attain 70% of the specified strength.

EXTENDED WET
A wet-curing period of 7 d at ≥ 10°C and for the time necessary to attain 70% of the specified curing strength. The curing types allowed are ponding, continuous sprinkling, absorptive mat, or fabric kept continuously wet.

**When using silica fume concrete, additional curing procedures shall be used. See Annex I, Clause 1.3.13*

Notes:
(1) Curing of plant production of precast concrete shall be as set out in CSA A23.4.
(2) It is recommended that concrete be allowed to air-dry for a period of at least one month after the end of the curing period, before exposure to de-icing chemicals.
(3) The rate of compressive strength gain in concrete is significantly reduced below 10 °C.

Sources:
1 Table 19, CSA A23.1:19/CSA A23.2:19 Concrete materials and methods of concrete construction/Test methods and standard practices for concrete. © 2019 Canadian Standards Association
2 Ontario Building Code – 2012, Ontario Ministry of Municipal Affairs and Housing – Housing Development and Buildings Branch
3 RMCAO Concrete Digest, Second Edition
4 Concrete in Practice #11 – Curing In-Place Concrete, National Ready Mixed Concrete Association

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:

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 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 A23.1-19– 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

CONCRETE ONTARIO VOICE OF THE CONCRETE INDUSTRY

WHO WE ARE

Concrete 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.

WHAT WE DO

Marketing and Promotion
Utilizing its technical and promotional expertise and resources, the Concrete Ontario 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.

CONCRETE ONTARIO ACTIVITIES

- Actively involved in Codes & Standards development with CSA
- Concrete Ontario Plant Certification
- Technical Publications
- Educational Activities:
  - ACI Field Testing Technician
  - ACI Concrete Flatwork Finishing/Technician
  - ACI Self Consolidating Concrete
  - Concrete College
  - Concrete Ontario Driver Certification
- Gold Seal Concrete Course
- Pavement Evaluation

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CONCRETE ONTARIO

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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

Social media sites:
twitter.com/concreteontario
youtube.com/concreteontario
linkedin.com/company/concrete-ontario

CARPENTERS UNION

Worker Training Programs

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.

WHAT WE DO

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

UNION LOCALS

Carpenters' District Council of Ontario	Tel: 905-652-4140 Fax: 905-652-4139
United Brotherhood of Carpenters and Joiners of America, Local 18 (Hamilton)	Tel: 905-522-0752 Fax: 905-522-0122
United Brotherhood of Carpenters and Joiners of America, Local 18 (Niagara)	Tel: 905-641-1877 Fax: 905-641-1809
Carpenters and Allied Workers Local 27	Tel: 416-749-7440 Fax: 905-652-4139
United Brotherhood of Carpenters and Joiners of America, Local 93	Tel: 613-745-1513 Fax: 613-745-3769
United Brotherhood of Carpenters and Joiners of America, Local 249 (Zone 1)	Tel: 613-384-3316 Fax: 613-384-3730
United Brotherhood of Carpenters and Joiners of America, Local 397	Tel: 905-885-0885 Fax: 905-885-0850
United Brotherhood of Carpenters and Joiners of America, Local 494	Tel: 519-737-1101 Fax: 519-737-1102
Drywall Acoustic Lathing and Insulation Local 675 of United Brotherhood of Carpenters and Joiners of America	Tel: 416-749-0675 Fax: 905-652-4149
United Brotherhood of Carpenters and Joiners of America, Local 785	Tel: 519-653-7543 Fax: 519-653-2837
United Brotherhood of Carpenters and Joiners of America, Local 1256	Tel: 519-344-2674 Tel: 519-344-2352 Fax: 519-336-4449
United Brotherhood of Carpenters and Joiners of America, Local 1669	Tel: 807-344-0611 Fax: 807-345-2548
United Brotherhood of Carpenters and Joiners of America, Local 1946	Tel: 519-649-1200 Fax: 519-649-1208
United Brotherhood of Carpenters and Joiners of America, Local 2041	Tel: 613-746-1265 Fax: 613-744-0912
United Brotherhood of Carpenters and Joiners of America, Local 2222	Tel: 519-396-0222 Fax: 519-396-6443
United Brotherhood of Carpenters and Joiners of America, Local 2486	Tel: 705-983-2486 Fax: 705-983-4345

LABOURERS' INTERNATIONAL UNION OF NORTH AMERICA

Strong, Proud, United

WHO WE ARE

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.

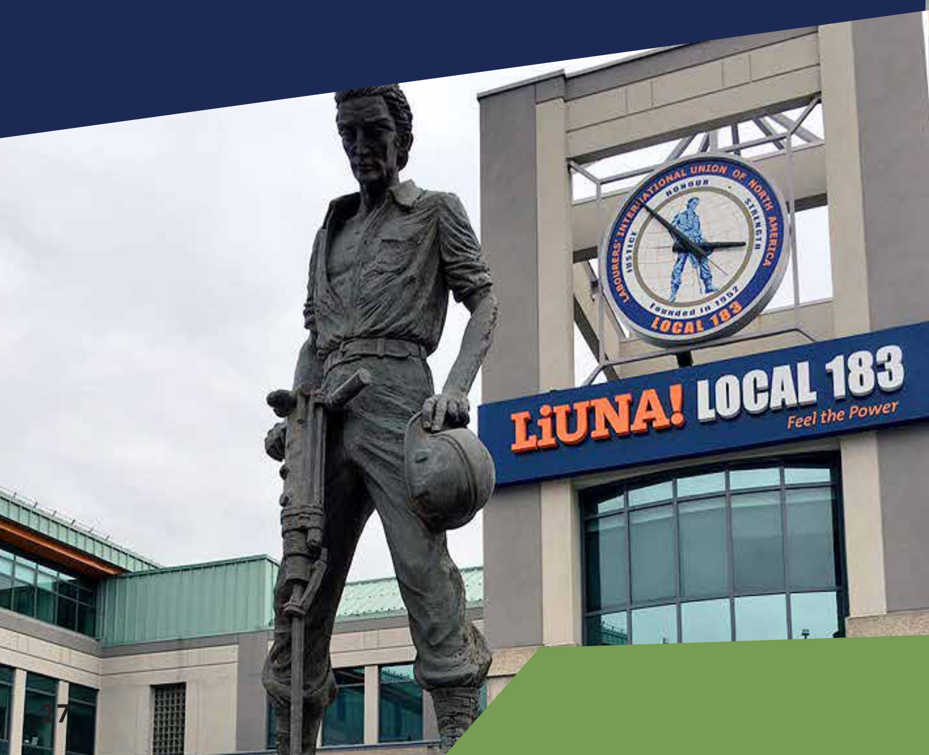
We strive, through our partnerships with management, to make the workplace a safer more productive environment by promoting strict adherence to provincially mandated and industry recognized standards which in turn ensure a long lasting relationship that is mutually beneficial in every facet.

Contact LiUNA

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

LiUNA!
Ontario Provincial District Council

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



IRON WORKERS

WHO WE ARE

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 they will challenge the Red Seal examination where they must obtain a minimum of 70% to change classification to Journeyman Reinforcing Rodworker.

WHAT WE DO

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
• Working @ Heights Certificate Training
• WHMIS 2015/GHS
• 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
Tel: (416) 236-4026 • cknowlton@iw721.org

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 765
Training and Rehabilitation Centre
7771 Snake Island Rd, Metcalfe On K0A 2P0
Tel: (613)-821-7813
Email: local765@ironworkers765.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:

Clinton Knowlton
Apprentice & Training Co-ordinator
Ironworkers Local 721
Tel: 647-449-7210 • cknowlton@iw721.org

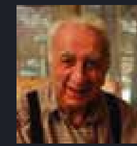
2018 Ontario Concrete Awards

STRUCTURAL DESIGN INNOVATION
HARBOUR RESIDENCES & ONE YORK

Location Toronto, Ontario
Completion December 31, 2017

Menkes Developments created an innovative mixed-use community with their Harbour Plaza Residences and One York office tower located in the South Core district of Toronto. The concept of the project was to incorporate a unique mixed-use development for residential and office space as well as a four-storey 200,000 retail podium. The whole development was created with the goal of starting a community which integrates live-work-shop-play, and more importantly minutes away from the subway (Union Station) via Toronto's PATH network.

Owner	Menkes Developments	General Contractor	Menkes Developments
Architect of Record	Sweeny &Co Architects Inc.	Forming Contractor	Hardwall Construction Ltd.
Harbour Residences Design Architect	architectsAlliance	Material Supplier	Innocon Inc.
One York Design Architect	Sweeny &Co Architects Inc	Additional Participants	• BASF Canada Inc. • LIUNA Local 183 • Salit Steel
Engineer of Record	Stephenson Engineering Ltd.		



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

ST. GABRIEL'S PASSIONIST CHURCH

2007 Ontario Concrete Award Winning Project For Architectural Merit

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. 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.

PROJECT CREDITS

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.

NATIONAL HOLOCAUST MONUMENT

Configured to create the points of a star, a symbol of Jewish identity

The National Holocaust Monument is a national symbol that honours and commemorates the victims and survivors of the Holocaust. The monument stands on a one-acre site in downtown Ottawa, symbolically across from the Canadian War Museum.

The monument is comprised of six triangular, concrete volumes configured to create the points of a star, a symbol of Jewish identity.

The project incorporated 90,000 square feet of custom engineered form work for walls with complex geometries and heights varying from 3 meters to 20 meters high.

Over 290 tonnes of custom detailed steel of varying sizes was used. Over 3,000 m3 of concrete was used, of which over 1,000 m3 was Self-Consolidating Concrete. The extensive use of Self-Consolidating Concrete was chosen because of its high performance, durability and because it required minimal use of mechanical vibration.

The flexibility of the Self-Consolidating Concrete allowed for an even, smooth flow and allowed the concrete to reach the most difficult parts of the forms, leaving a superior exposed architectural finish, maintaining consistent concrete features that produced continuity from one element to the next.

Hand painted monochromatic photographic landscapes of Holocaust sites are embedded in concrete walls of each of the triangular spaces. A significant portion of the project was constructed during the winter months, which required temporary heated enclosures and constant monitoring of temperatures and curing conditions.

Hard and soft landscaping, removal of contaminated soil, site servicing, electrical, mechanical, landscape lighting, custom metal work and commemorative interactive signage elements rounded out this iconic project.

PROJECT CREDITS

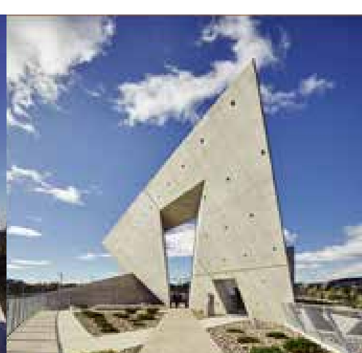
Owner	National Capital Commission
Architect of Record	Studio Libeskind
Engineer of Record	Read Jones Christoffersen Ltd.
General Contractor	UCC Group Inc.
Material Supplier	Hanson Ready Mix

Additional Participants

- Aluma Systems Inc.
- Carpenters Union Local 93
- Claude Cormier + Associes
- Harris Rebar
- Ironworkers Local 765
- JWK Utilities & Site Services Ltd.
- LiUNA Local 527
- Sika Canada
- WSP Canada Inc.

PROJECT FACTS

Location	**Ottawa, Ontario**
Completion	**September 2017**
Details	**• 1 acre site • 290 tonnes of rebar • 3,112.5 m³ of concrete**

Ontario Cast-in-Place Concrete Development Council (OCCDC)

1 Prologis Blvd., Unit 102B
Mississauga, ON L5W 0G2
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Fax: 905-564-5680
Email: buildings@occdc.org

www.occdc.org

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.