Precast/Prestressed Concrete Infrastructure Construction

Technical Guide

Canadian Precast/Prestressed Concrete Institute

Index

Infrastructure

The Concise Oxford Dictionary defines infrastructure as "a system of airfields, telecommunications, and public services forming a basis for defence." According to Webster's New World Dictionary, infrastructure is defined as "the substructure or underlying foundation, especially the basic installations and facilities on which the continuance and growth of a community or state depends".

When we think of infrastructure we think of built infrastructure such as roads, electric power lines and water systems as well as social infrastructure such as schools, hospitals and libraries.

Structural & Architectural Precast Prestressed Concrete

Few building materials available today offer the economy, flexibility and reliability of precast prestressed concrete. The scope of applications is exceptional.

Durability

Durability is a function of the material and the environment. Precast prestressed concrete will provide reliable long-term performance in extremely harsh conditions that can destroy lesser materials. Precast prestressed concrete is resistant to deterioration from weather extremes, chemical attack, fire, accidental damage and the determined efforts of vandals.

Precasting concrete in a plant allows CPCI members to exercise precise control over the reinforcement and the concrete materials; placing and curing variables that affect durability, strength and appearance. Dense impermeable concrete can readily be produced by carefully controlling the materials, slump, water/cement ratio, air entrainment and the curing process. All CPCI member plants manufacture in accordance with CSA standard A23.4 "Precast Concrete - Materials and Construction". Precast is certified by CSA to CSA Standard A251 "Qualification Code for Architectural and Structural Precast Concrete Products."

Speed

Precast concrete components lend themselves to fast construction schedules. Precast manufacturing can proceed while site preparation is underway. Precast units can be delivered to the job site and installed when needed all year round. Fast construction means earlier completion and the resulting cost savings.

Flexibility

Advances in production methods are permitting precast manufacturers to vastly expand the design possibilities of precast components.

Many different types of forming systems permit CPCI members to take maximum advantage of the inherent plasticity of concrete to create precast components in shapes and sizes, which would be prohibitively expensive using other materials.

Economy

Standard structural shapes such as hollow core, double tees, beams, girders, columns and panels can be mass-produced at low cost.

Where custom-engineered products are desired, careful design work can assure maximum economies of scale through repetitious casting.

Beauty

Precast components can be delivered with a wide range of shapes and finishes ranging from smooth dense structural units to any number of architectural treatments.

Strikingly rich and varied surface textures and treatments can be achieved by exposing coloured sands, aggregates, cements and colouring agents using sandblasting and chemical retarders.

Custom forms and liners can be used to introduce reveals, patterns and other architectural effects. Stone, tile brick and other materials can be cast into precast panels at the factory, enabling designers to achieve the expensive look of stone masonry at a fraction of the price.

Infrastructure Distress

Investigations show that the majority of bridge maintenance organizations employ life cycle costing and value engineering, in contrast to most new construction, which is commonly based on lowest bids.

Environmental mechanisms describe deterioration as a consequence of causal factors and exhibits both macroscopic and microscopic scales.

Interactive mechanisms describe deterioration as a result of distress at a location influencing the deterioration of neighboring locations and exhibits on a microscopic scale.

The primary cause of infrastructure deterioration and ensuring maintenance is from corrosion caused by road deicing salts. Salt-water environments and other sources of corrosion are a distant second. A cost analysis based on annual highway department budgets for bridge inspection, maintenance, rehabilitation and replacement indicates that provinces cannot keep up with the problem of bridge degradation due to corrosion, especially by rehabilitation or replacement.

Certified precast concrete elements manufactured in CPCI member plants are capable of providing long lasting solutions for infrastructure construction. Precast prestressed concrete can be deployed in infrastructure applications to achieve:

1) corrosion mitigation,
2) reinforcement of degraded bridge components,
3) seismic protection, and
4) low-cost erection / low-cost maintenance.

CPCI members are willing to work closely with cities, municipalities, provincial department of transportation and engineering consultants to:

1) understand their needs and requirements,
2) educate them in the technology and uses of precast concrete materials, components, systems and structures,
3) assist in finding long-lasting, economical precast prestressed concrete solutions, and
4) cooperate with organized demonstrations to encourage innovative uses of precast concrete components for both new and rehabilitating existing structures. These components can be fabricated using existing technology, installed and monitored in the field.

Corrosion Protection

Protection of reinforcing steel from corrosion can be obtained by proper embedment in concrete. A protective iron oxide film forms on the bar as a result of the high alkalinity of the cement paste. This protection is usually lost by leaching and carbonization. Concrete with sufficiently low permeability and adequate cover will protect the reinforcement. Hairline and structural cracking may allow oxygen and moisture to reach the reinforcement, providing conditions where rusting of the steel and staining of the concrete may occur.

Secondary protection methods include prestressing (eliminate or reduce cracking), galvanizing and epoxy coatings on embedded steel, stainless steel, corrosion inhibitors and membranes.

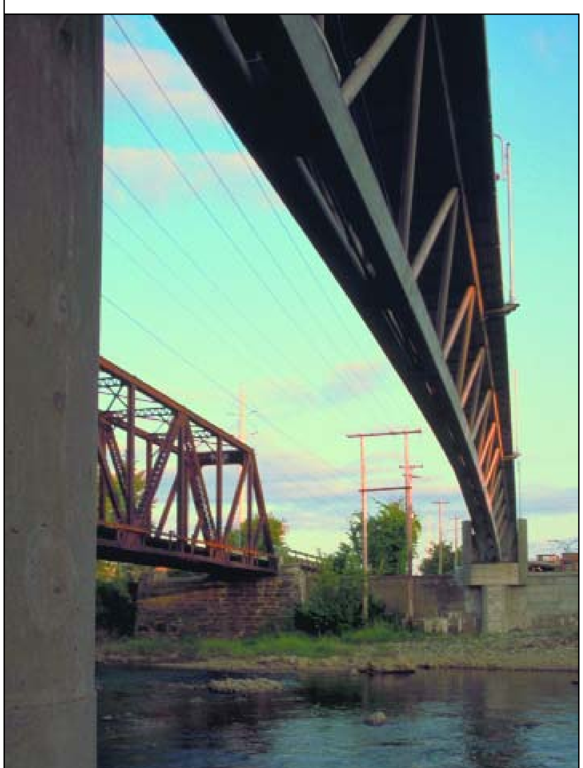
For a more detailed discussion of this topic, see the CPCI Design Manual, Third Edition, and the PCI Architectural Precast Concrete Manual, Second Edition.

High Performance Concrete (HPC)

"High performance concrete (HPC) is defined as concrete which meets special performance and uniformity requirements that cannot always be achieved using only the conventional materials and mixing, placing and curing practices. The performance requirements may involve enhancements of placement and compaction without segregation, long-term mechanical properties, early age strength, toughness, volume stability, or service life in severe environments." - ACI 1993.

Many infrastructure owners are demanding an extended service life and want reassurance prior to construction that it will be achieved. It is widely accepted that life-cycle costs for HPC structures will be lower than those of similar structures using conventional concrete. First costs for the use of HPC may be higher unless the structural benefits of higher strength concrete can be realized. Bridges and other structures can now be specified for a designed service life of 50, 80 or 100 years.

The impermeability of concrete cover is paramount and should be the first line of defense against the physio-chemical deterioration processes that our infrastructure is subjected to. Prestressing enhances durability by placing the concrete in compression and eliminating most cracking at service loading conditions. CPCI members are in the best position to provide the benefits of HPC. Precast elements are cast in factories under very controlled conditions. Quality control is carefully supervised. Products and processes are monitored and certified by CSA. The concrete and the cover to the reinforcement are carefully controlled. The controlled curing of concrete in a precast plant can have a significant positive impact on the subsequent durability of the concrete. Cast-in-place HPC will normally contain silica fume. Precast concrete may not, particularly where the main parameter is high strength. Consult with CPCI members when developing HPC requirements for specific projects.



The ASTM C1202-97 "Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration", commonly called the Rapid Chloride Permeability (RCP) Test is sometimes used as a measure of concrete permeability. Maximum coulomb ratings at 28 and 91 days are specified and verified by test.

Reference:

A State-of-the Art Review of High Performance Concrete Structures Built in Canada: 1990-2000, John A. Bickley, Denis Mitchell, May 2001, Cement Association of Canada

Non Metallic Reinforcement (FRP)

Infrastructure components that commonly deteriorate over time (usually by corrosion) can force early rehabilitation. Fibre reinforced polymer (FRP) composite materials may be used to reinforce these sections to allow the infrastructure to achieve its full lifetime.

ISIS Canada

ISIS Canada is a collaborative effort of Canadian universities specializing in civil, mechanical, materials, aerospace, and electrical engineering to study intelligent sensing for innovative structures (ISIS). ISIS was established in 1995 to research and develop innovative uses of fibre reinforced polymers (FRPs) in concrete structures that are prone to deterioration because of corroding steel reinforcements. As a means of documenting the behaviour of FRP, ISIS Canada also researches and develops structurally-integrated fibre optic sensing systems that allow engineers to monitor structures from remote locations.

For more information, go to: www.isiscanada.com

Fibre Reinforced Polymers (FRPs)

Glass and carbon FRPs are up to 6 times stronger than steel, one-fifth the weight, non-corrosive and non-magnetic. Their high strength and light weight, and the fact that FRPs are now available in the form of very thin sheets, make them an attractive alternative and economical solution for strengthening existing concrete bridges and structures.

In new structures and bridges, the use of FRP bars and tendons is considered to be one of the most promising solutions to overall deterioration aggravated by corroding steel reinforcements.

Precast girder bridges using FRP prestressing tendons have been built by CPCI member companies in Alberta, Manitoba and Michigan.

Composite material components should be used in applications where standard metallic components incur high maintenance costs due to corrosion and its effects.

Two approaches could be:
- Direct material substitution to composite materials, or
- Precast concrete facings incorporating composite materials to shield structures (i.e. to redirect deicing salt run-off with a corrosion-resistant structure).

Typical applications could include bridge piers, decks, expansion joints and handrails.

Concrete Materials & Design Standards

CSA Standard A23.1 - Concrete Materials and Methods of Concrete Construction

CSA Standard A23.2 - Methods of Test for Concrete

These standards are referenced in the National Building Code and give the technical requirements for cast-in-place concrete. Test methods for predicting performance and evaluating minimum levels of quality are given in CSA A23.2.

CSA Standard A23.4 - Precast Concrete - Materials and Construction

CSA Standard A251 - Qualification Code for Architectural and Structural Concrete Products

These standards cover precast concrete construction. A23.4 covers the technical requirements for precast concrete. In most cases, the requirements are higher than cast-in-place concrete because of the closer control possible in a precast plant. Precast concrete products are certified by the Canadian Standards Association. The A251 standard outlines the procedures, controls and documentation required for certification.

CSA Standard A23.3 - Design of Concrete Structures

This standard covers the design requirements for most concrete structures (except bridges). Clause 16 Precast Concrete covers the design requirements for precast concrete. An improved concrete material resistance factor is allowed for certified precast concrete structural members. Clause 18 Prestressed Concrete covers the design requirements for pretensioned and post-tensioned concrete.

CSA Standard S413 - Parking Structures - Structures Design

Many parking structures are unheated and subject to large short and long-term temperature variations. Most parking garages are exposed to the corrosive effects of deicing (road) salt. The quality of precast construction and the beneficial effects of prestressing are recognized in this standard.

CSA Standard S6 - Canadian Highway Bridge Design Code

CSA Standard S6.1 - Commentary on the Canadian Highway Bridge Design Code

This standard covers the design of highway bridges. Clause 8 covers Concrete Structures and Clause 8.7 covers Prestressing Requirements. Other specific requirements for precast concrete bridge construction are outlined in Clause 8.

CSA Standard S806 - Design and Construction of Building Components with Fibre Reinforced Polymers

Canada is the first country with a building code for FRP. FRP are also recognized in CSA Standard S6 - CHBDC.

The latest editions of these CSA publications are available for online ordering from the Canadian Standards Association website at: www.csa-intl.org/onlinestore/

Guide Specifications

SPECIFICATION - Section 03450 - Architectural Precast Concrete

SPECIFICATION - Section 03450 - Insulated Precast Concrete Wall Panels

SPECIFICATION - Section 03410 - Structural Precast/Prestressed Concrete

SPECIFICATION - Section 03410 - Hollow Core Precast/Prestressed Concrete

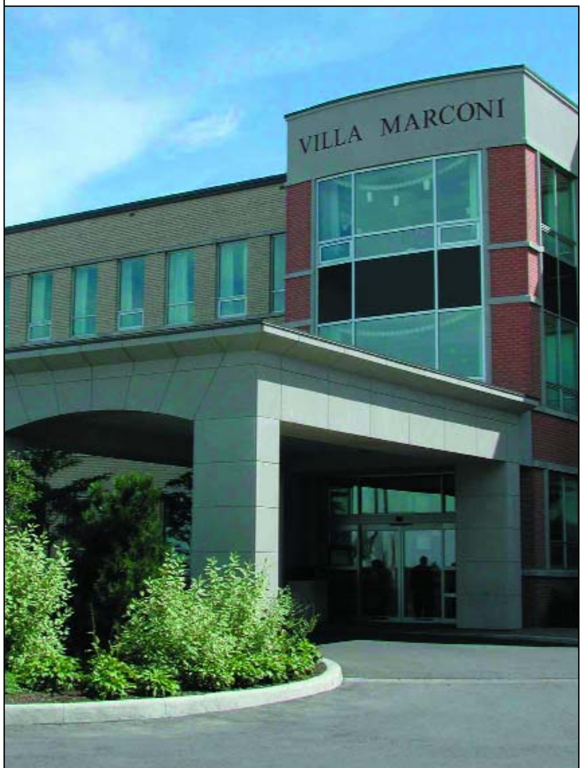
These updated guide specifications are available for downloading at the CPCI website: www.cpci.ca

Precast Concrete - An Intelligent Material for Infrastructure Construction

In addition to their primary role of providing a safe and secure environment for the service, education and activities for the public, today's schools and public buildings double as a communities' public shelters in the event of hurricanes, tornadoes, earthquakes, snow storms and other disasters.

Reinforced concrete, as a basic raw material, already has many attractive advantages over steel. It has high mechanical strength. It is cheaper than steel. Beam and slab continuity reduces deflection and bending moments, and results in lighter members. Fire resistance is an intrinsic quality. Acoustical insulation is achievable through mass. Thermal capacity can be taken advantage of. A variety of shapes, textures and colours are possible. Concrete has a long technical life expectancy. A limited amount of maintenance is required.

Precast concrete adds to these advantages. Improved performance is achieved with less variation than with cast-in-situ concrete, due to close control of quality and tolerances during production. Precast eliminates the need for formwork and scaffolding and consequent site obstruction. A wider range of instant finishes is possible. Precast is a fast construction method. Transportation - elements can be readily delivered to the site when needed. Pre-maturing eliminates shrinkage cracks. The advantages of prestressing - reduces the size of members and a consequent further decrease in dead weight



Fire resistant precast concrete building components make them the ideal non-combustible building material. Fire ratings of one to four hours are available. Precast doesn't burn. It doesn't give off smoke or toxic fumes when exposed to fire. Concrete doesn't fuel the fire. Concrete maintains its structural integrity and can be designed for effective containment of fires, keeping fires from spreading to other parts of a building. This results in more time to evacuate safely and extinguish the fire and little chance of injury or damage outside of the area where the fire started. This means savings in insurance and liability costs. The public is better protected in the event of an emergency.

Precast concrete walls and structural precast floors and roofs are impermeable to damage by termites and other pests, control exterior and interior noise and vibration and damage due to mould, humidity, corrosive materials and direct impact.

Taxpayers rely on administrators and designers to provide maximum value when building new and expanded facilities. Construction deadlines, manageable budgets, highly functional facilities and low maintenance are all critical concerns when planning new public projects.

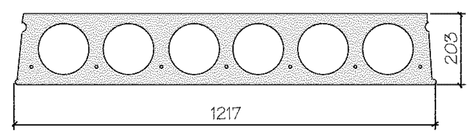
Design requirements for large, open areas such as libraries, gymnasiums, field houses, auditoriums and cafeterias can easily be met by precast prestressed structural systems. Slender, long spans, capable of carrying heavy loads, reduce building height. Precast concrete wall panels can be designed as load bearing - removing the need for interior framing. Precast structural systems can clear span gymnasiums and swimming pools for a result that also resists corrosion from humidity, chemicals and impact damage for the life of the structure. In addition, a precast enclosure offers excellent noise containment and reduces vibrations.

Structural & Architectural Precast Concrete Systems

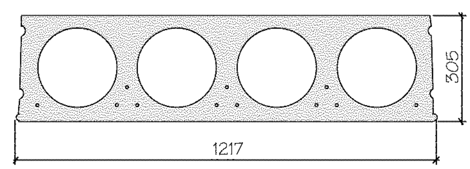
No other building material can match the long-term durability, low-maintenance and cost-reduction qualities of precast concrete. Many structures require large, unobstructed open plans for flexible space planning. Precast offers flexible building systems that encourage and enhance new approaches to meet the changing needs of modern buildings. Precast is cost-competitive, consistently high quality and offers more flexibility than most other structural and cladding materials.

Hollow Core Slabs

Hollow core slabs are constructed using low-slump concrete and high strength prestressing strands. Continuous voids are formed through each unit to reduce weight and improve structural performance. Slabs are typically 1220 mm wide (4'-0"). The most popular depths are 203 mm (8 in) for spans to 9.8 m (32 ft) and 305 mm (12 in) for spans to 13.7 m (45 ft). Contact your local CPCI member for specific sizes, span/loading and detailing information.



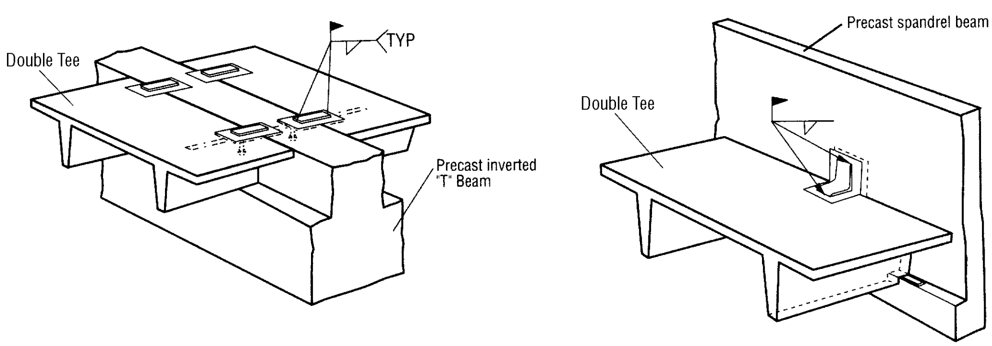
203mm slab



305mm slab

Precast Prestressed Double Tees

Consider double tees for those longer spans and heavier loads that exceed the capacity of hollow core slabs. Double tees have evolved from 1220 mm (4'-0") widths to 3000 mm (10'-0") and 3660 mm (12'-0") or more. Depths can vary from 300 mm to 1000 mm. Spans can range from 10 to 25 m for floor loadings to over 33 m for roofs. Double tee dimensions are based on many factors (design efficiency, most popular usage, fire regulations, transportation regulations). Contact your local CPCI member for specific sizes, span/loading and detailing information.



Typical Double-Tee Detail

Precast Framing Systems

Precast beam and column framing systems provide incredible flexibility in layout. Frames can be massive and strong or light and delicate. Most CPCI structural precast producers have standard shapes and sizes for columns, beams, walls and stairs. These sizes can be modified and customized to suit specific project requirements. Prestressing beams will reduce construction depth and allow longer clear spans. Lateral forces can be resisted by cantilevered columns, diagonal bracing, shear walls, frame action or a combination of methods. Contact your local CPCI member for specific sizes, span/loading and detailing information.

Precast Concrete Wall Systems

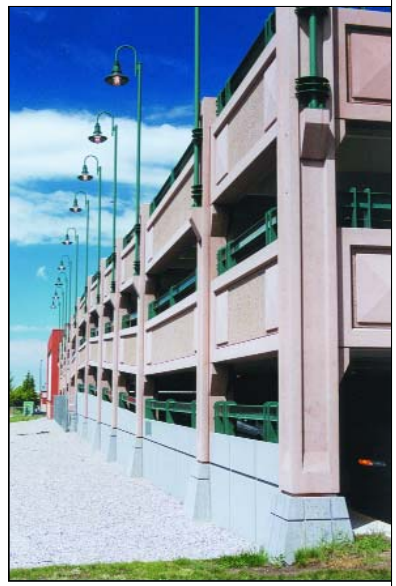
Precast concrete insulated sandwich wall panels are economical and will enclose a building faster than any other structural system to help complete an entire project more quickly. Panels are available in a wide range of custom and standard widths, lengths, thicknesses, R-values and exterior finishes. Contact your local CPCI member for specific sizes, span/loading and detailing information.

The true benefit of architectural precast concrete is found in the virtually limitless aesthetic effects that can be achieved from its use. Custom forms are used to create precast panels in the exact size and shape using reveals, patterns, shapes and other architectural detailing specified by the designer. Colour effects can be achieved using various coloured sands, aggregates and cements. Textures can be customized with the use of retarders, acid washes and sandblasting. Contact your local CPCI member for recommended panel sizes, design and detailing information.

Fast Construction

Shorter construction timetables and the ability to more accurately pinpoint completion and occupation dates are critical in planning new facilities. Precast, construction is more predictable. Extremely short schedules are possible as precast components are factory constructed in CPCI member certified plants. Precast erection can proceed on a steady schedule year round in any weather. Precast components are delivered to the work site ready to install directly from the truck. Precast decks provide an immediate work platform so other trades can start sooner.

Parking Garages



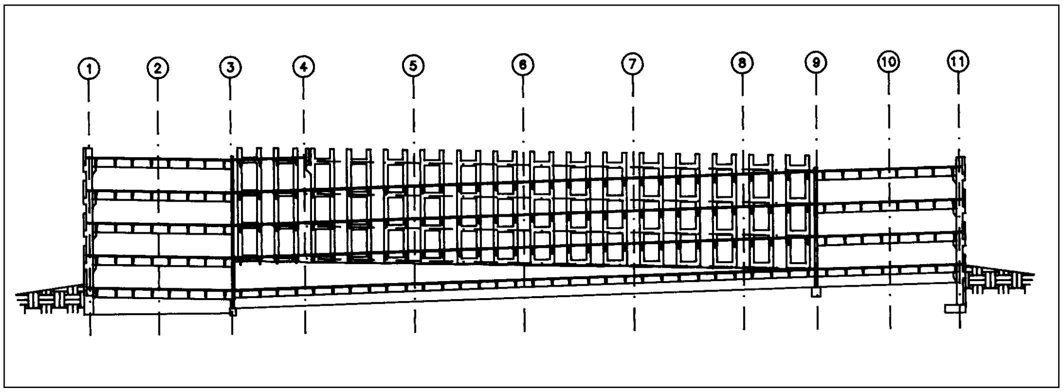
Parking structures often represent the first and last impression a visitor has when visiting an airport, hospital, public building or recreation centre. Excellent parking structures are designed specifically for the types of visitors a structure will serve, based on the facilities they support and the daily or peak flows of traffic. Unless a parkade is safe, secure and easy-to-use, parkers will find other options.

Creating the best parking structure to fit a site, the users and budget requires a careful balance of all elements and a logical plan from start to finish. The early involvement of your local CPCI member while key design decisions are being made can make a dramatic difference to the final result. Their expertise and input can minimize the time and cost required to complete a project. Precast parkades offer fast construction, versatility of design, attractive exterior finishes, durability and economy; making precast prestressed concrete a popular choice for commercial, municipal and institutional clients.

Exterior Finishes

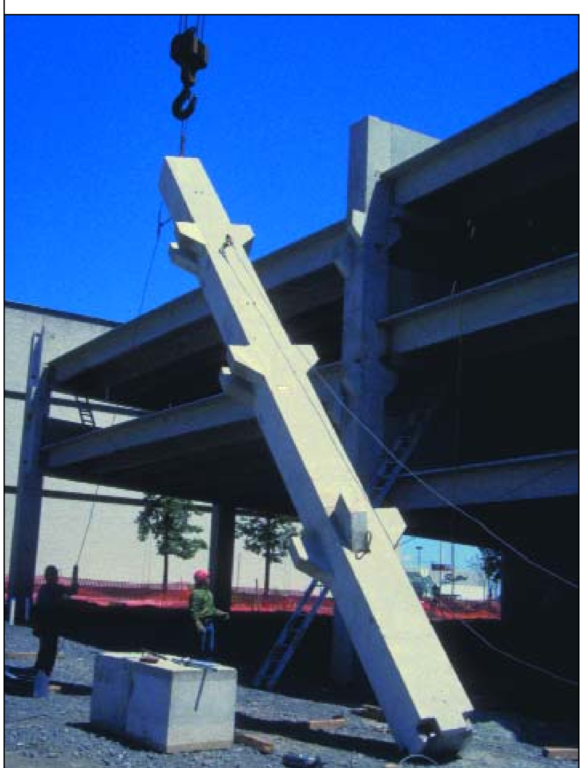
Precast parking garage exteriors can be delivered with a wide range of shapes and finishes ranging from smooth dense structural units to any number of architectural treatments. This will allow a whole range of exterior treatments from a bold contemporary look to one that blends in with older neighbourhoods.

Strikingly rich and varied surface textures and treatments can be achieved by exposing coloured sands, aggregates, cements and colouring agents using sandblasting, acid etching and chemical retarders. Custom form liners can be used to introduce reveals, patterns and other architectural effects. Stone, tile brick and other materials can be cast into precast panels at the factory, enabling designers to achieve the expensive look of masonry at a fraction of the cost.



Loads and Forces

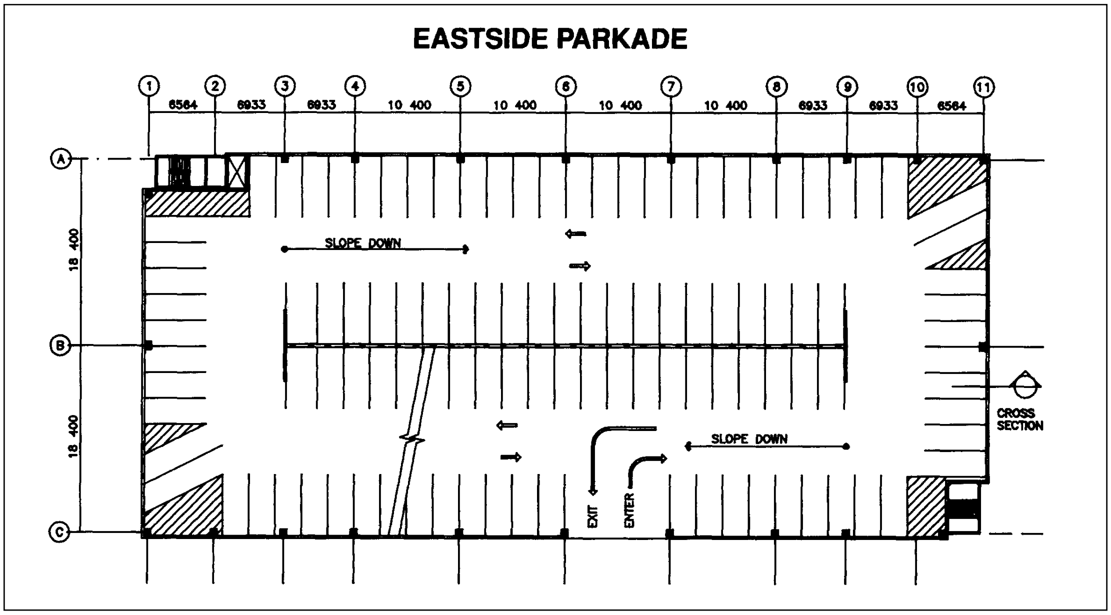
Precast concrete parking structures allow for volume changes from creep, shrinkage and temperature differences. Components are cured before they are delivered to the site. The connections between members allow the structure to relieve pressures from ordinary expansion and contraction that otherwise could cause cracking in structural elements. Lateral design loads for wind, earthquake or earth pressures (for in-ground or partially buried structures) can be resisted in a precast concrete structure by transferring loads through the floor diaphragm to shear walls and/or to column beam frames. Care in locating shear walls, the adequate isolation of shear walls and the introduction of adequate isolation and expansion joints will assure satisfactory performance.



Loading walls with framing beams or floor members can minimize connections between shear walls to resist uplift forces. The torsion resistance of eccentrically loaded beams and spandrel panels must be considered. Connections can be designed to prevent beam rotation and absorb bumper loads (if applicable) without undue restraint against volume changes.

Bay Sizes

For maximum economy, bay sizes should be as large as possible and modular with the standard precast concrete floor elements selected. For clear span parking, the bay size selected need not be a multiple of the width of the parking stall. Cranked (bent up or down) double tees can be used to accommodate complex geometric layouts.



Drainage

Sloping the structure to achieve good drainage is essential to quickly remove rain and salt laden water from the structure. The drainage pattern selected should repeat for all floors to allow for repetition in manufacturing the precast elements. Locate isolation (expansion) joints at high points to minimize possible leakage. Slope the floors away from columns, walls and spandrels where standing water and leakage could cause corrosion.

Durability

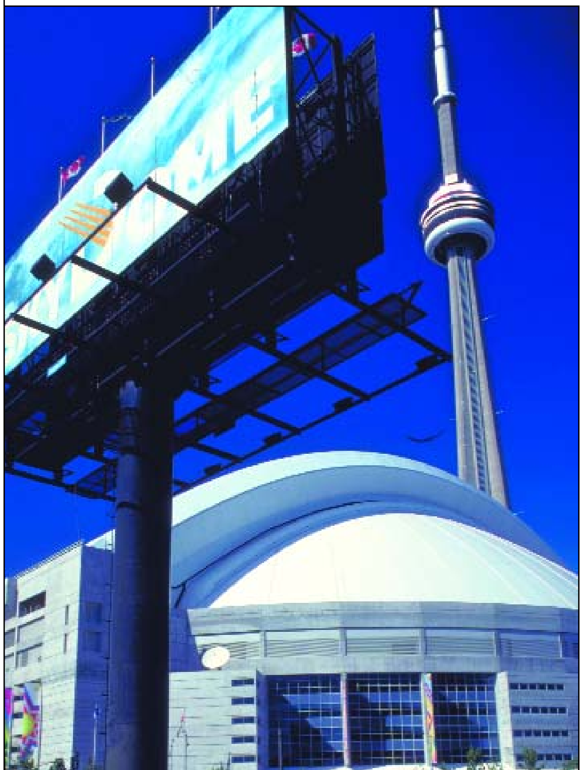
High strength factory produced precast reinforced and pretensioned concrete components have been found to be highly resistant to attack by chloride ions. Where cast-in-place composite topping is used over precast floor members, wire mesh reinforcement should be incorporated in the topping. Good results have been achieved by providing a high strength concrete topping having a water cement ratio of 0.40 or less. Concrete containing 6% entrained air and at least five days of curing under wet burlap will produce the best results.

Pretopped double tees are a recommended alternative to field-placed concrete toppings. An advantage of this system is that it produces an excellent 35 to 55 MPa plant produced wearing surface - instead of a lower strength field placed concrete topping. The top surface is typically broom-finished to provide improved driving traction. Special considerations are critical for adjacent camber differential, joint treatments, erection stability and drainage with this system. CSA Standard S413 specifies requirements for low-permeability concrete, acceptable protection systems and concrete cover for reinforcement and prestressing tendons.

A series of control joints should be provided in the topping above all joints in the precast members below. Later these joints are cleaned, prepared and filled with a recommended sealant.

Except for column base plates, all connections and exposed hardware often use hot dipped galvanized or stainless steel. Where connections are subsequently welded, the welds should be minimal and located where they can be easily maintained.

The application of a penetrating sealant to the concrete surfaces is usually a good investment to help inhibit water and chloride ion penetration. Studies have shown that precast prestressed parking garages have performed well over the years. A regular maintenance program is a good investment to keep a parking structure long lasting and trouble-free.



Stadiums & Arenas

Large stadiums and arenas are impressive structures. Often these projects are built on tight budgets and schedules to accommodate some important sporting event. Precast prestressed concrete has been the overwhelming choice for many of these projects.

The technique of post-tensioning precast segments together has allowed precast concrete elements to form complex cantilever arm and ring beam construction to support the roofs of these structures. Post-tensioning is also commonly employed to reinforce precast concrete cantilevered raker beams, which carry the seating and provide unobstructed viewing of the playing surface.

Mass produced seating units are manufactured in a variety of configurations and spans to provide for quick installation and long lasting service. Pedestrian ramps, concession, toilet, and dressing room areas can all be framed and constructed using precast prestressed concrete elements.

Transit Structures

Transit Facilities

Precast prestressed concrete has become the structural and architectural system of choice for a variety of transit facilities.

No single construction material lends itself to a more dazzling array of architectural treatments than precast prestressed concrete. Rich aggregates, decorative shapes, reveals and attractive stone and masonry veneers can all be employed to express a wealth of architectural detail.

Quality precast concrete, produced and erected under stringent quality controls, effectively resists corrosion and damage and retains its good looks for years with no significant staining, discolouration or surface decay. Required maintenance is low - saving plenty of money and inconvenience over the life of the structure.

Elevated Guideways

Transit Stations

Terminals

Privacy & Protection

Sound Walls

Sound barriers, positioned along the edges of major roads and highways, can reduce the transmission of direct sound to residential areas. Barriers should be as close to the sound source as possible and block the direct path of the sound. Sound reaching a residential area will be limited mainly by diffraction over the top of the wall when there are no significant sound leaks and the wall has a mass exceeding 20 kg/m^2. Having a sound absorbing surface on the side of the barrier that faces the traffic will increase the sound attenuation.

Precast concrete sound walls have many advantages over wood, masonry and metal panelling. Precast concrete walls and pilasters can be manufactured in a wide variety of finishes, textures, patterns and colours. Panels can be finished on both sides to present a finished appearance to the roadway and the protected properties behind. Precast sound walls can be installed quickly in any weather. Precast concrete is environmentally friendly and does not involve cutting down trees or the use of toxic wood preservatives. Precast sound walls are manufactured locally. They have excellent resistance to wind, seismic, snow plows and vehicle impacts. Precast sound walls resist corrosion and vandalism. Panels can be sealed to ease the removal of graffiti. Costs can be a major factor, particularly when calculations include a material's entire life cycle - from production to manufacture to disposal. A Colorado study assumed a service life of 15 years for wood, 30 years for masonry and 40 years for precast concrete post and panel sound walls.

Contact your local CPCI members to discuss sound walls.

Fences

Retaining Walls

Retaining walls provide lateral support to vertical slopes of soil. Retaining walls can be constructed of many different precast materials and with a variety of building techniques. Retaining wall design and wall type selection are driven by several factors; cost, required wall height, ease and speed of construction, ground water conditions and soil characteristics as well as building codes, site accessibility and aesthetics.

Designing a retaining wall requires knowledge of lateral earth pressure. It is possible to engineer an attractive long-lasting, precast concrete retaining wall structure that will meet all foreseen environmental, structural and construction demands.

Several soil parameters must be determined before an engineer can assess a particular wall design and its overall stability:

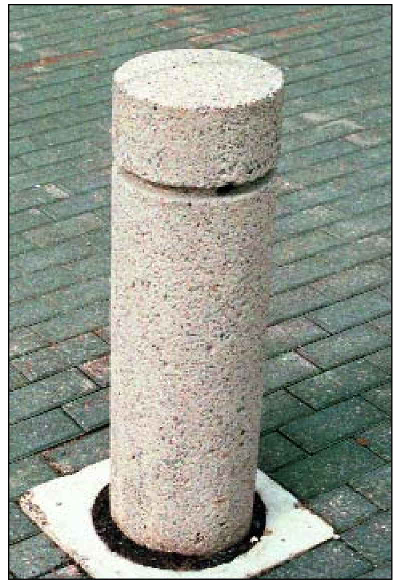
- soil unit weight
- angle of internal friction of the soil
- cohesion and plasticity indices for cohesive soils (for instance, clays)
- water table location.

Once the lateral earth pressures are known, a wall can be checked for stability. This includes checks for wall overturning, base sliding, and soil bearing capacity failures.

Segmental retaining walls consist of a facing system and a lateral tieback system. The facing systems usually consist of modular concrete blocks that interlock with each other and with lateral restraining members. The lateral tiebacks are usually geogrids that are buried in the stable area of the backfill. In addition to supporting the wall, the geogrids also stabilize the soil behind the wall allowing higher and steeper walls to be constructed.

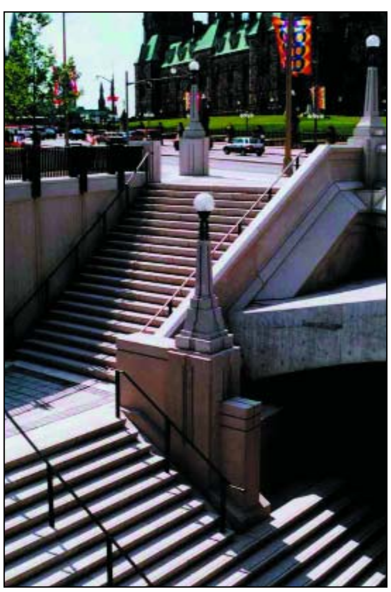
Counterfort retaining walls have vertical precast concrete columns at regular intervals along the wall. These counterfort columns are T-shaped, may be tapered at the back and are anchored to the foundation by reinforcing or post-tensioning. Precast concrete panels are placed between the flanges of the counterfort columns to hold back the earth. Counterfort retaining walls resist the shear forces and bending moments imposed on the wall by the soil. Counterfort retaining walls are usually more economical than cantilever walls for heights above 7.5 m (25 ft).

Precast concrete crib wall systems use high strength precast concrete standard basket type units that are stacked and filled with earth for stability. After planting with ground cover, the wall becomes part of the natural environment. These walls offer stability and fulfill the concerns of citizens by providing sound reduction while conforming to the natural landscape. Crib walls can be used as retaining walls or slope stabilizers for earth or rock embankments, or as a noise free standing barrier; especially suitable for highways, railroads and parks, gardens, residential and commercial districts.



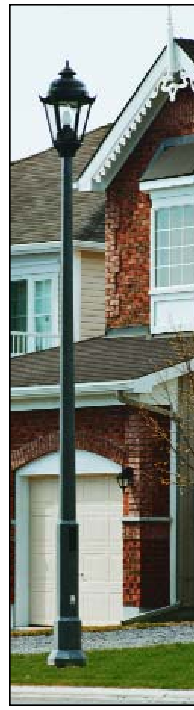
Landscaping

Precast concrete landscape units are often used to beautify an urban setting. The look can be modern or rustic, simple or complex. A wide range of colours and architectural finishes are available. Consult your local CPCI member for input and cost information early in the design process.



Utilities

Light Poles and Utility Poles



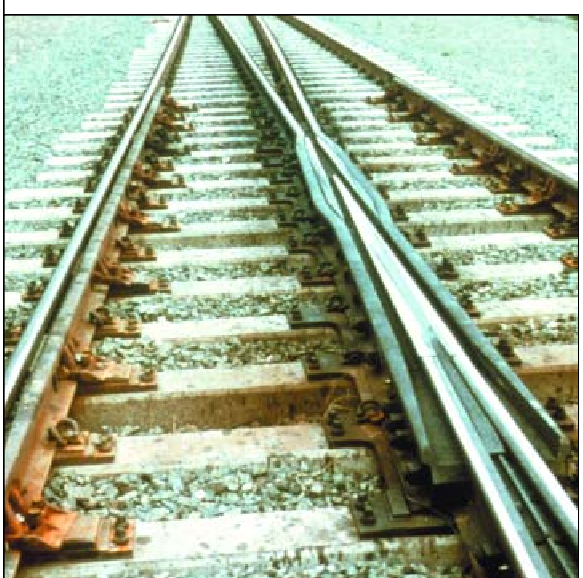
Low maintenance, competitive price, and aesthetic appearance of precast concrete poles make them superior to steel or wood for use in utility, sports lighting, communication and area lighting applications. The ease and speed of installation means faster project completion and lower installed costs. Also, the use of concrete poles preserves our forests, requires no chemical treatment, and utilizes environmentally safe materials in production and placement. Some other benefits are corrosion resistance, long service life - in excess of 50 years, cost effective - both installed and service life.

Precast concrete poles can save erection time and money by eliminating the need for anchor base structures which may take days or weeks to install. A precast concrete pole, under most conditions can be set in hours (drill a hole, place the pole, backfill with crushed aggregate, concrete or the original soil, then finish off with concrete or sod). This process eliminates unsightly base plates, studs or nuts that are normally used with steel poles.

Utility Products (Vaults, Culverts, Etc.)

Many CPCI members make both standard and custom utility products. Consult a CPCI member near you.

Rail and Track Ties



Freight Handling/Storage Buildings

Docks & Wharfs

Precast prestressed concrete is used extensively for the construction of docks and wharves, particularly on our East and West coasts - where marine traffic is highest.

Precast construction is the ideal material for building over water where weather conditions are variable and access is usually limited. Precast prestressed piles are often used to support dock structures. Precast fender panels can be designed to resist ship impact loads. Precast prestressed deck units will support heavy traffic loads on longer spans.

Precast concrete can be designed for long service life in harsh environments. The use of high strength low permeable concrete will protect the reinforcement and resist environmental damage.

Tanks

Precast/Prestressed Concrete Effluent Treatment and Storage Tanks

Precast concrete tanks provide extra security for the contents and save time and money. Precast tanks can store or treat anything from potable water to hazardous waste to solid material. Storage capacities can range from 0.4 to 120 megaliters (100,000 to 30 million gallons). Precast concrete wall elements are usually pretensioned vertically in the precast plant and post-tensioned horizontally through ducts cast in the panels. Joint closures are usually poured concrete on site. This method of sealing the joints allows the tank to perform (after post-tensioning) as a monolithic structure to resist hydraulic, temperature and seismic forces.

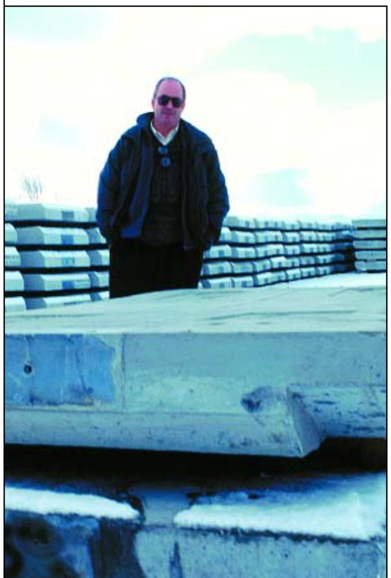
Off-site fabrication of wall and roof elements (under extremely well controlled conditions in a CPCI member precast plant) means higher quality and reduced labour on-site. Virtually any storage structure can be built using precast concrete. Other parts of a tank structure, such as columns, beams and roof slabs, may also be precast concrete. Contact CPCI for more information and design recommendations.

Prisons

Precast concrete has been put to good use for a variety of detention and correctional facilities and the support buildings that serve a vital role in institutional complexes. Precast concrete wall panels, framing and floor/roof slabs are excellent building components that are both durable and secure. Exterior walls can be sandwich panels with a layer of rigid insulation between whythes of reinforced or prestressed concrete. Special security hardware is often specified. Security door and window frames can be pre-installed in the precast concrete elements at a CPCI member precast plant to save time and money.

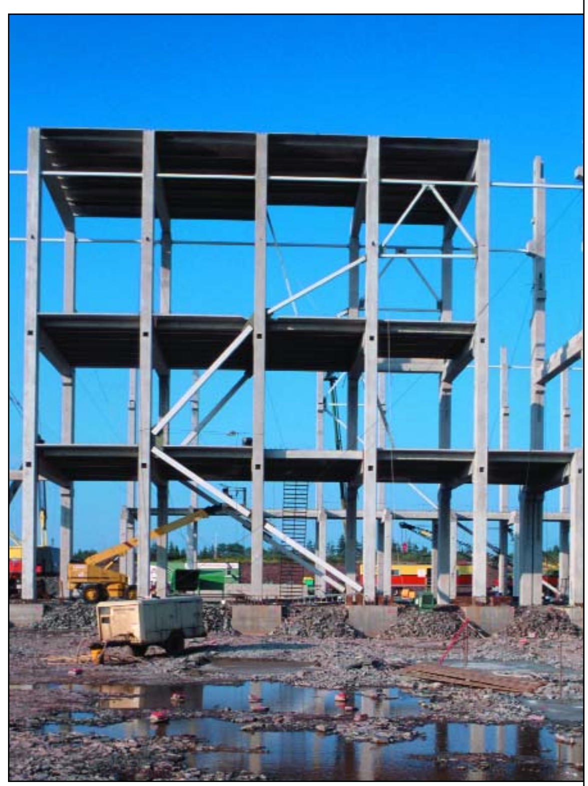
On very large-scale projects, custom forms can be designed to produce special units such as entire single and double cell units. Otherwise, standard precast components can be successfully modified for prison construction. As in most precast structures, using practical and economical joint details is most important. All joint treatments should recognize realistic production and erection tolerances. Exterior joints should allow movements and be weatherproofed to prevent air and water infiltration. When joints are exposed in high security locations, they are generally sealed with high strength, non-shrink grout. This material can be used to seal narrow joints and fill the cavities over recessed structural connections.

Water & Sewage Treatment Plants



Special Applications

A high degree of design flexibility makes architectural and structural precast prestressed concrete ideal for a wide variety of innovative structures. Properties such as corrosion resistance (piling), durability (railway ties), fire resistance (pipe racks), tight tolerances (tunnel liners), architectural finishes (chimney stacks), strength (silos) and fast installation and economy (water tanks), are all used to good advantage. Where repetition and standardization exist, precast components can economically provide quality, plant manufactured products and eliminate expensive and risky field procedures. New applications await the collaboration of creative designers and CPCI members.



Vehicle & Pedestrian Bridges

Proven Economy

There were no prestressed concrete bridges in North America prior to 1950. Thousands of prestressed bridges have now been built in the past 50 years and many more are under construction in all parts of Canada and the US. They range in size from short span bridges to some of the largest bridge projects in the world. The design of prestressed concrete bridges is covered by CSA Standard CAN/CSA-S6-00 Canadian Highway Bridge Design Code specifications.

Prestressed Girder Bridges

Precast prestressed concrete bridges have gained wide acceptance because of:

1. Proven economic factors:
   a. low initial and long-term cost
   b. minimum maintenance
   c. fast easy construction
   d. minimum traffic interruption

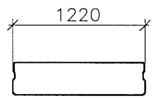
2. Sound engineering reasons:
   a. simple design
   b. minimum depth-span ratio
   c. assured plant quality
   d. durability

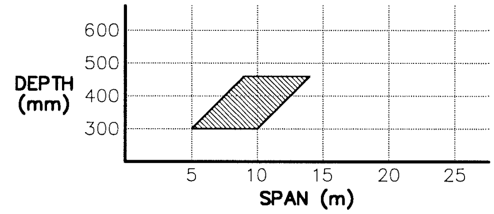
3. Desirable aesthetics - precast prestressed bridges can be designed to be very attractive.

Bridge designers are often surprised to learn that precast prestressed bridges are usually lower in first cost than other types of bridges. Coupled with savings in maintenance, precast bridges offer maximum economy.

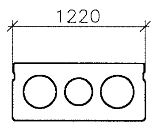
Girder Types

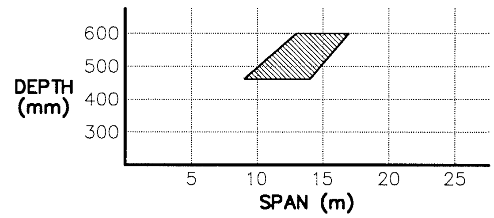
Consult your local CPCI members for standard sizes in your area.



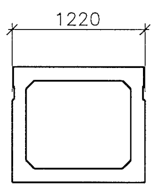


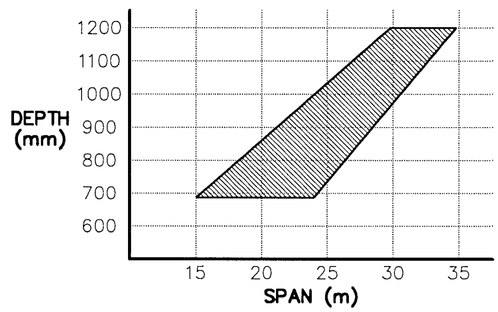
Solid Slab Girders



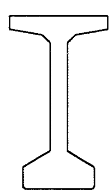


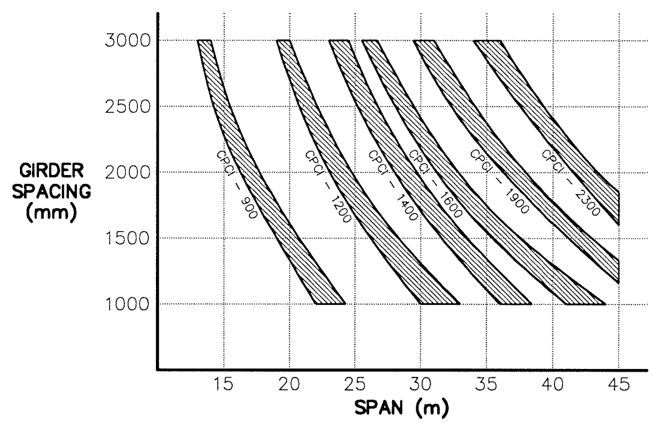
Hollow Slab Girders



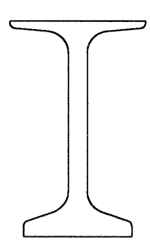


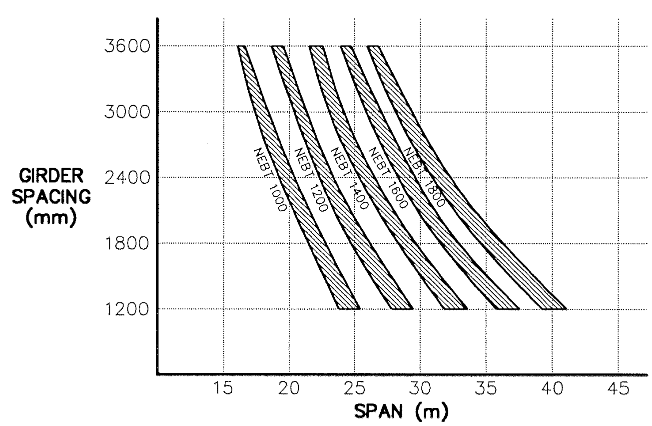
Box Girders





I-Girders





Bulb Tee Girders

Benefits of Precast Prestressed Concrete for Bridge Construction

Low Initial Cost

Precast prestressed concrete bridges are usually lower in first cost than other types of bridges. Precast bridges offer maximum economy with savings in time and maintenance.

Fast Easy Construction

Precast prestressed bridge girders require minimal lead times because they are locally manufactured in standard shapes and sizes. The precast components are easy to erect all year round. Simple connections join the deck girders to the substructure.

Formwork for the superstructure can be eliminated when the tops of girders are placed together to form the entire deck slab. Ties between adjacent units often consist of a grouted keyway and welded or transverse post-tensioned connections. For logging or low volume secondary roads, traffic can run directly on the girder deck.

Carefully planned details will speed the construction process and save money.

Minimum Traffic Interruption

Maintaining traffic and eliminating detours are difficult problems for bridge owners. Precast prestressed concrete integral deck bridges can minimize traffic interruption because of the availability of long span, plant-produced sections and the speed of erecting a bridge. In emergencies, precast girders can be rush ordered and a bridge reopened in a matter of days or weeks using standard components.

Simple Design

Replacement of substandard bridges can be easily accomplished with precast prestressed sections. In some cases, existing abutments can be reused. In others, precast concrete piles, footings, abutments, wingwalls and piers can be precast and installed along with the deck girders.

Simple span precast bridge deck girders can be pinned to the abutments to resist horizontal earth pressures or be designed as integral abutments to eliminate troublesome expansion joints. Multi-span bridges can be made continuous for a smoother ride and to reduce the number of expansion joints.

Assured Plant Quality

Precast prestressed concrete products are inspected and quality controlled at the plant. Each operation in the manufacturing process provides an opportunity for inspection and control. During fabrication, prestressed beams are proof tested at release of prestress and subjected to some of the highest stresses they will ever encounter in service. CPCI member plants manufacture certified products per the CSA Program for Architectural and Structural Precast Concrete in accordance with CSA Standard A23.4 "Precast Concrete - Materials and Construction".

Durable

Bridges are subjected to hostile environments as well as repeated impact loading. These structures must withstand not only freezing and thawing but artificial cycles of weathering and chemical attack through the use of deicer chemicals. High strength air-entrained precast prestressed concrete has excellent resistance to freeze-thaw and chloride attack. Prestressing enhances durability by placing the concrete in compression and eliminating most cracking at service loading conditions. Also, precast prestressed concrete bridges are non-combustible and resistant to damage by fire.

Attractive

Precast prestressed concrete bridges can be designed to elegantly blend harmoniously with their surroundings and offer an attractive view from above, beside and below. Strong, tough, durable yet graceful bridges can be constructed using the low depth/span ratios possible using high strength precast prestressed concrete and the simple clean shapes of locally available sections.

Minimum Maintenance

The overall economy of a structure is measured in terms of its life-cycle cost. This includes the initial cost of the structure plus the total operating cost. For bridges, the operating cost is the maintenance cost. Precast prestressed concrete bridges designed and built in accordance with CAN/CSA-S6-00 Canadian Highway Bridge Design Code specifications should require very little, if any, maintenance. Precast prestressed members are particularly durable because of the high quality of materials and construction used in their manufacturing.

Fatigue problems are minimal because of the minor stresses induced by traffic loads.

Of course, no painting is needed. Some bridge engineers estimate the life-cycle cost of re-painting steel bridges to be 10 to 20% of the initial cost. Painting bridges over busy highways, over streams, or in rugged terrain is very expensive and an environmental concern.

Shallow depth/span ratio

A common requirement of many bridges is that the superstructure be as shallow as possible to provide maximum clearance and minimum approach grades. Through the technique of pre-stressing, the designer can use the minimum possible depth-span ratio. Depth-span ratios as low as 1:32 can be achieved with solid slabs, voided slabs, box beams, channel slabs or bulb-tee sections. Even though deeper I-girder and bulb-tee sections will require less prestressing steel, the overall economy of a project may dictate the lowest possible depth-span ratio.

Contact your local CPCI members to discuss your next project.

Planning

1. Use locally available precast concrete members. The hauling distance for precast concrete bridge members is generally limited to about 500 km except under unusual circumstances. Precasting plants are equipped to furnish certain types of members. For short span bridges, designs using standard bridge sections will result in lower bid prices than unique designs.

2. Make precast members identical. Economy in precast manufacturing results from the production of identical sections. As an example, if a bridge consists of different span lengths, it is usually better to design all of the precast units with the same cross section rather than to design each span for an optimum depth-span ratio.

3. Work closely with local CPCI members throughout the planning stages. Ask for cost estimates as soon as sufficient data or plans are available so that cost savings can be incorporated well before bids are taken.

4. Set up bridge replacement programs to group several bridges into single contracts for optimum savings in fabrication, hauling, erection, and supervision.

5. Use county or municipal work forces and equipment, when available, to perform most of the site work on small bridges.

6. For prestressed concrete bridges with cast-in-place deck slabs, use diaphragms only if required for erection purposes. Studies have shown that diaphragms contribute very little to the distribution of static or dynamic loads. Diaphragms at piers and abutments, i.e. those over supports, are useful in stiffening the slab edge.

7. Minimize skews wherever possible. If a skew is necessary, try to limit the skew to 30° or less. It may be less costly to lengthen the bridge slightly than to use an extreme skew angle to fit the bridge site exactly.

8. Use precast prestressed piles to double as foundations and piers where soil conditions are favourable. If pile foundations are warranted, prestressed concrete piles can serve as piers and abutments, thereby reducing the amount of on-site forming and concreting.

9. Use integral deck girders to eliminate the need for cast-in-place concrete deck slabs and to speed-up construction.

Detailing

1. Eliminate projections from the sides of the girders. Most precast prestressed concrete members are cast in precision-made steel forms. Form projections can be accommodated only by expensive modifications to the forms. It is better practice to use details that permit attachment by use of threaded inserts, weld plates, or through bolts to bolt or cast on projections after the girder is cast.

2. Use standard details recommended by local CPCI member manufacturers. Those are the details that can be made most economically.

3. Minimize the amount of reinforcing steel in prestressed concrete members. There is a tendency to add more reinforcing bars and welded wire fabric than is needed "just to be safe." Often the added reinforcement merely creates congestion making consolidation of the concrete difficult without contributing to the structural strength or behaviour.

4. Use elastomeric pads instead of metal bearing assemblies. Elastomeric pads, properly designed and installed, require no maintenance and will permit movements (due to temperature, shrinkage, and loads) to occur without distress.

References:

Wong, A.Y.C., and Gamble, W.L., "Effects of Diaphragms in Continuous Slab and Girder Highway Bridges," Civil Engineering Studies, Structural Research Series No. 391, University of Illinois, Urbana, Illinois, May, 1973.

Sengupta, S., and Breen, J.E., "The Effect of Diaphragms in Prestressed Concrete Girder and Slab Bridges," Research Report 158-1F, Center for Highway Research, The University of Texas at Austin, Oct. 1973.

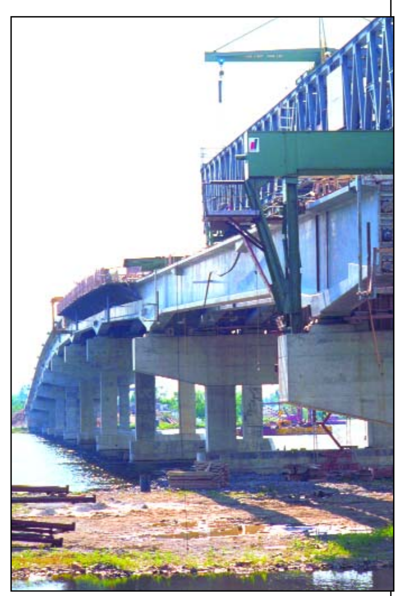
Spliced Girder Bridges

Up until the mid 1960's, transportation equipment and available cranes limited the length of precast pretensioned girders to around 34 m. Some innovative designers began to look for ways to use the economy and high quality of plant produced precast girders for longer span bridges. Canadian engineers led the way in constructing long span prestressed precast girder bridges using spliced beams. Precast girder segments of manageable weight and length are transported to the site. Girder segments are either spliced and post-tensioned on the ground and launched or the girder segments are erected on temporary supports in their final position and post-tensioned together. Normally, precast girders can be fabricated and transported in lengths of 40 to 50 m and weights of up to 75 to 90 tonnes. The spliced girder method of construction has extended the practical use of precast beams to span lengths of 75 m or more by joining and post-tensioning girder segments at the site.

The benefits of a precast spliced girder system are:

Economy
Fewer piers result in lower overall cost, especially where soil conditions are problematic.

Safety
For overpasses, fewer piers result in longer sight distances and more spacious horizontal clearances. There is less likelihood of vehicle collisions with supporting columns.



Navigation
Across waterways, fewer piers allow improved navigation, better movement of ice and debris and minimal disruption to the natural environment.

Deck Joints
Fewer joints result in a smoother driving surface and less maintenance.

Aesthetics
Long span bridges are more attractive.

Types of Splices

Reinforced splice

Precast girders are cast with splicing reinforcement projecting from the ends. The beams are positioned end-to-end on a temporary support, usually near the dead load inflection point, and concrete is cast-in-place at the splice. The girder segments are usually pretensioned to resist shipping and handling forces.

Cast-in-place post-tensioned splice

Precast girders are placed on falsework or temporary end supports, usually locate near the dead load inflection points. The joint is poured and continuous post-tensioning is applied. Mechanical keys are often used. Sinusoidal keys work well because they transfer shear more uniformly.

Stitched splice

This splice is a compromise between reinforced and post-tensioned splices. The ends of pretensioned segments are clamped together by short cables or threaded bars.

Drop-in splice

This splice is used when the erection of a temporary support is not feasible (e.g. over river crossings or traffic lanes). The splice may be designed as a hinge or post-tensioning may be applied locally to induce continuity.

Structural steel splice

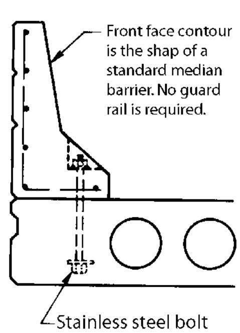
Steel plates are cast in the ends of girder segments to overlap at the matching ends of precast units. The plates are bolted together temporarily while free standing without support. The joints are later welded together and encased in concrete.

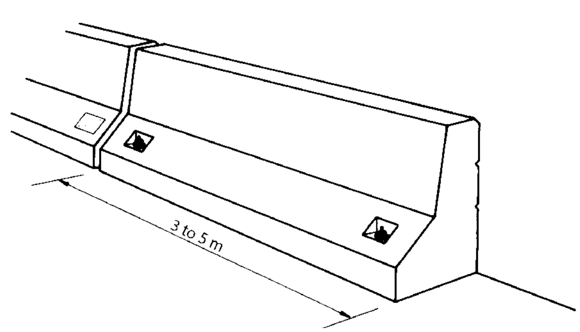
Epoxy-filled post-tensioned splice

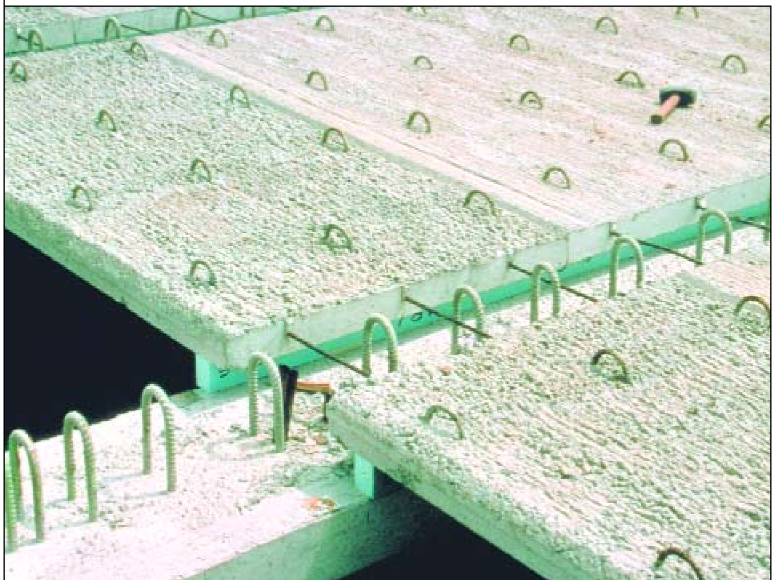
Girders are aligned end to end, either in their final position or on the ground. The gap is filled with epoxy gel or grout and later the post-tensioning force is applied. A compressible gasket often protects the post-tensioning duct splice area. Match casting, while not essential, allows precision placement and expedites the work.

Spliced girder bridges have been constructed all across Canada with very good results. They allow the use of quality factory-made components for spans much longer than those spans where girders can be transported as single spans.

Traffic Barriers





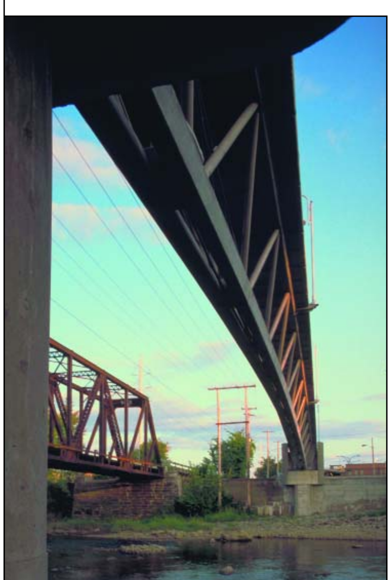


Bridge Decks

Bridge decks often wear out well before the supporting beams. Some provinces have evidence that concrete bridges are more rigid than steel bridges and this results in superior deck performance (less cracking and longer life).

Precast concrete composite bridge deck panels are 75-100 mm thick slabs that span between the top flanges of concrete or steel beams. The panels provide a working platform for deck reinforcement placement and a stay-in-place form for the cast-in-place concrete overlay. Prestressing strands in the panels are perpendicular to the longitudinal axis of the beams and provide all of the positive reinforcement required for the span of the deck between beams. The panels are shimmed to the correct height and become composite with the cast in place overlay to resist superimposed dead and live loads.

Full depth precast concrete bridge deck panels are used to replace worn or corroded decks on bridges where traffic must be maintained during the construction. Prestressing strands in the panels are perpendicular to the longitudinal axis of the beams and can be in two layers to provide all of the positive reinforcement required for the span of the deck between beams. The panels are shimmed to the correct height. Shear studs on the beams are grouted in place through pockets in the deck slabs. Edge grouting and longitudinal post-tensioning are usually used to tie the deck panels together.



Consult your local CPCI structural precast concrete manufacturer for their standard panel sizes and reinforcing layouts.

Pedestrian Bridges

Precast prestressed concrete is an ideal solution for pedestrian bridges. Bridges can range from simple double tees, bridge I or box girders to elegant custom-made cable stayed or reactive powder concrete (RPC) trusses for road and river spans that enhance the user's enjoyment of the crossing.

Guide Specification for Bridge Components

General:
These specifications cover materials, fabrication, transportation, and erection of all precast concrete bridge components as shown on the plans.

Materials:
It is recommended that materials conform to the following requirements. Where ASTM specifications are cited, the latest edition is applicable unless otherwise indicated.

Prestressing strands (1860 MPa, seven-wire) - ASTM Standards A416M, A421 and A722
Reinforcing bars - CSA Standards G30.3, G30.5, G30.14, G30.15 CAN/CSA GG30.18 or ASTM Standards A184, A497, A704 or a775
Welded wire fabric - ASTM Standard A497
Normal weight aggregate - CSA Standard A23.1
Lightweight aggregate - ASTM Standard C330
Portland cement (Type 10 or 30) - CSA Standard A5

Concrete compressive strength of at least 28 MPa at transfer of prestress and 35 MPa at 28 days is recommended. Concrete exposed to freezing and thawing while wet, such as bridge decks, piling, and abutments, should have an air content of 6% ± 2%.

Design:
The bridge should be designed in accordance with CAN/CSA-S6-00 Canadian Highway Bridge Design Code for a CL-625 Truck loading. It is recommended that the design provide for a future wearing-surface unless otherwise noted.

Qualifications of Manufacturer:
1. Fabricate precast/prestressed concrete elements certified by CSA International in the appropriate category(ies) according to CSA Standard A23.4-00 "Precast Concrete - Materials and Construction" and to CSA Standard A251-00 "Qualification Code for Architectural and Structural Precast Concrete".

2. The precast concrete manufacturer shall be certified in accordance with the CSA Certification program for Architectural and Structural Precast/Prestressed Concrete prior to submitting a tender and must specifically verify as part of his tender that he is currently certified in the appropriate category(ies):

Spec Note: *Delete the categories that do not apply.*

(A) Precast Concrete Products - Architectural
(I) Non-Prestressed or (II) Prestressed
(B) Precast Concrete Products - Structural
(I) Non-Prestressed or (II) Prestressed
(C) Precast Concrete Products - Specialty
(I) Non-Prestressed or (II) Prestressed

3. Only precast concrete elements fabricated by certified manufacturers are acceptable to the Owner. Certification must be maintained for the duration of the fabrication and erection for the project. Fabricate precast concrete elements in accordance with _____________(Province/Municipality) Bridge Code requirements.

4. The precast concrete manufacturer shall be a member in good standing with the Canadian Precast/Prestressed Concrete Institute (CPCI) and have a proven record and satisfactory experience in the design, manufacture and erection of precast concrete facing units of the type specified. The company shall have adequate financing, equipment, plant and skilled personnel to detail, fabricate and erect the work of this Section as required by the Specification and Drawings. The size of the plant shall be adequate to maintain the required delivery schedule.

Spec Note: *CPCI Members have access to the latest information and technology. CPCI Members are dedicated to providing the highest levels of quality and customer service. For a current list of CPCI Members, see: www.cpci.ca/activemember.html.*

Fabrication of Precast Concrete Units:

The use of steel forms founded on concrete casting beds is recommended. Voids formed by any approved material, must be securely held in place during casting, and should be vented during casting and curing. Box-beam voids should be fitted with bottom drain tubes. All exposed corners should be chamfered or rounded (preferably 20 mm). Dimensional tolerances should conform to those suggested in CSA Standard A23.4. Chairs, spacers, or bar supports in contact with forms should be plastic tipped or made of plastic. The top surface of precast sections that will receive cast-in-place topping should be roughened with a stiff bristle broom. A wood float finish or a light broom finish at right angles to the length of the section is recommended for the top surface of precast integral deck units.

Transportation and Erection:

During handling, flexural members must be maintained in an essentially upright position at all times and picked up only by means of approved devices at locations indicated on the plans. During transport, members should be supported only at approved locations (near the pick-up points).

For More Information:

CPCI Design Manual,
Third Edition
order from: www.cpci.ca

SHAPING YOUR VISION

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