

PCI Research Needs List

November 2019

Category	Subject	Comments
Parking Structures	Durability enhancement in precast concrete parking structures including performance of double tee flange connections and joint leakage	All material and installation requirements need to be included in the study
Seismic	Improved diaphragm connection performance when subject to earthquake loading	Connection characteristics are defined – new connections need to be qualified. In particular, high deformability connections in shear and tension are needed for more severe SDC's.
	Simplified seismic connections for precast concrete shear walls	
	Enhanced Joint Shear in Hybrid Moment Frame Columns	Currently the HMF system comes at a cost premium to a Concrete Special Moment Resisting Frame(SMRF). This cost is mostly due to the fact that columns in HMF systems need to be larger to accommodate the larger joint shear as well as the reduced column cross section due to the duct. If we could come up with a way to enhance the joint shear of the column by 25% +/- it could help make this system more cost compatible with an emulative SMRF
	Refine Ω_v in ASCE 7-16 Diaphragm design	This factor currently makes untopped diaphragms impractical in regions of high seismicity. This factor was derived from a parametric study completed during the DSDM research. Understanding that this is having a large impact on our systems a more in depth study is justified to refine or validate this factor.
Anchorage to Concrete	Effects of reinforcement in anchorage concrete breakout zones	
	Simplification of anchorage calculations	Combine with a study of LW vs NW concrete
	Anchorage of standard hooks with transverse reinforcement inside hook bend	Currently we are limited to L_d for standard hooks controlled by breakout and crushing in the bend. These lengths will increase due to changes in ACI 318-19. There is no research to support reduced L_d values when transverse reinforcement is placed inside the bend to resist breakout cracking and to spread the crushing/bearing stresses from the bar tension.

	Dowel action as an alternative to shear friction	ACI 318 does not cover dowel action in connections. New provisions in ACI 318-19 add shear-lug design that shares strength with studs with dowel mechanism that is not explicitly defined.
	Simplified connections of prestressed bridge girders to deck	
	Reduction of volume change restraint forces in bearing pads	The N_u force used in bearing calculations can be calculated if the shear stiffness or slip stress of bearing pads is known.
	Post-tensioning anchorages in hybrid frames	Early research on the hybrid frame indicated potential issues with P-T anchors under cyclic load
	Application of headed bars in precast concrete connections	Compare headed bars welded to plates to headed concrete anchors
Wall Panels	Crack mitigation for insulated panels with continuous insulation	
	Effect of reinforcement to improve edge lifting devices in thin panels	
	Effective stiffness of vertical panel groups mechanically connected across vertical joints	Concern is how to evaluate the effective stiffness of such panel groups considering the flexibility of connections across vertical joints for proper modeling of systems. ACI 318 permits the design of special moment frames of precast concrete considering strong or ductile connections. The Code does not afford the same consideration for connections in vertical joints of precast concrete walls. The design of strong or ductile connections requires the characterization of wall stiffness as well as strength and/or ductility in these connections for design to be standardized.
	Seismic Design for wall panels with horizontal joints without minimum wall steel crossing the joints	ACI 318 permits the design of special precast concrete shear walls that meet the requirements for CIP special structural walls and the connection requirements for intermediate precast concrete structural walls. An interpretation of these provisions is that the joints between walls are connections, and do not require the minimum wall reinforcement to cross the joints. This is disputed by some building officials. Research is needed to characterize the joint-opening and plastic-region behavior of walls

		without minimum wall steel, but with debonded length of vertical reinforcement in the ends of the walls to increase the strain distribution near the joints.
Erection	Temporary bracing design for vertical precast members and partially erected structures	
	Probability study for temporary bracing loads	Provide design guide for address temporary loads
	Tripping and rotating erection methodology	
	Productivity in the field	More efficient connections to replace welding in order to release product from the crane quicker to allow more pieces to be installed per day.
	Drone and/or laser scanning use for layout , clash detection and as-builts	Is a 3D point cloud produced by a drone's LiDAR survey accurate enough to use for layout for erection, clash detection in a BIM model and for as-builts.
Systems	Hybrid frame application to disproportionate collapse	Hybrid frames used for seismic resistance may have significant capacity for disproportionate collapse
Component Design	Improved detailing of double tee bearing plates	
	Shear strength in end regions of pretensioned members	In particular, this should address anchorage of longitudinal reinforcement for reliable shear strength.
	Headed deformed bars as shear reinforcement*	
	Effects of partial debonding of prestressing strands	Include consideration of lightweight concrete
	Release stresses in pretensioned members	Consider all sections where compression and tension must be considered
	Post cracking shear strength of bridge girders using self-consolidating concrete	
	Use of high strength reinforcement for spirals in prestressed concrete piles or prestressed columns	Can allowable yield strength of spirals be increased to 120 or 150 ksi?
	Minimum spacing requirements for large prestressing strands	
	Inverted tee or spandrel beams that require more prestress than a plant can pull on beds/abutments	How to determine strength and stresses for combined pretention (with strain compatibility) and unbonded post-tensioning (without strain compatibility)

	Hangers for openings in hollow core slab systems	Explore different hanger designs and effectiveness including support of reaction at adjacent members.
	Deflection calculations for Class T and C prestressed flexural members	Examine available data to evaluate current calculation methods and propose better methods
	Determination of plate-bending applications of eccentric transverse loading (torsion) for prestressed concrete beams with aspect ratios less than 4.5	Current limitations on plate-bending design are based on available research and are likely more conservative than needed.
	Rational determination of A'_{sh} reinforcement requirements in dapped ends.	Current requirements for A'_{sh} steel area (horizontal reinforcement at the bottom of the member) is given as "not less than A_{sh} ." The requirement for reinforcement at the bottom of the beam is likely less than that for diagonal tension at the re-entrant corner, and the requirement creates difficulties in detailing.
	Surface roughness required for tension and shear bonding between cast-in-place concrete topping and precast concrete members for composite design	Requirements for measured surface roughness and the relationship between roughness and strength are not prescribed in sufficient detail to support rational design for composite members without transverse reinforcement.
	New cost effective flooring system design that can be cast on long-line steel prestress beds	For total precast concrete building construction where double tees may be overkill and hollowcore may not work or may not be available. The system should be conducive to receiving integral plumbing, HVAC piping and/or electrical conduit.
	Through testing and analysis, examine the longitudinal splitting strength of hollow core slabs subject to point loads and line loads parallel to the span	Some guidance is available on splitting strength under point loads but nothing is available for heavy line loads parallel to the span.
	Effects of joint size and configuration in hollow core systems subject to non-uniform loads	Building tolerances may require joints between slabs to increase in size and many layouts require splits creating non-standard joint configurations. The effects on load distribution are to be studied.

	Concrete compressive ϕ factor in seismically confined columns	$\phi=0.65$ was developed for concrete columns years ago. At the time, spiral reinforced columns were given a higher ϕ because they provided more confinement than a typical column. The current phi factors correlate to #3 or #4 ties at roughly 16" OC wrapping every other leg. A seismically tied column today looks more like #5 ties at 4 inches oc. This added confinement that provides seismic ductility also makes the column capacity much more reliable. AISC uses $\phi=0.9$ for compression in columns and $\phi=0.75$ for composite columns. A seismically confined column should have similar if not superior performance to a steel or steel composite column. This should be explored this to determine if a higher ϕ is justifiable in seismically tied columns.
Sustainability	Development of tools for Life Cycle Assessment of parking structures	Sustainability assessment of parking structures requires new criteria to understand the benefits of high performance precast concrete construction
	Development of detailing to enhance resiliency in precast concrete structures	As compared to other construction materials, precast concrete has opportunities for superior resiliency for fires and natural events.
	Development of better tools to assess the positive effects of thermal mass on operational efficiency of structures	
Materials	Cement replacement in concrete mixes	Sustainable concrete specific to precast
	Characteristics of SCC	Include creep, shrinkage, early age modulus and shear strength
	Structural design guidelines for sand lightweight concrete	
	Effects of elevated temperatures from fire on fiber reinforcement and FRP composites in precast concrete structural members	
	Rate of tensile strength gain vs compressive strength gain in lightweight concrete	This information would contribute to knowledge on early age strength of anchorage in concrete
	100 year life for structure and repairs	Bridges and, eventually, parking structures will have requirements for a 100 year life. Materials and detailing need development to meet this requirement.

	Delayed ettringite formation (DEF)	This research will evaluate the use of the “delta ettringite” testing method, which was developed as part of a PCI funded study in the late 1990’s. This proposed work will extend the scope to include measurements of concrete at later ages.
	Improved flexural strength in concrete mixes to make the product less susceptible to cracking especially in high-end architectural product.	Stresses are generally held to $5\sqrt{f'c}$ for design with no discernible cracking. Rather than a UHPC that concentrates on high compressive strength, this research should concentrate on a high early flexural strength that may or may not correspond to the currently accepted ratios between the two strengths
Architectural Precast	Effect of moisture content on APC color	Architectural panel color can be judged at many different ages. What is the effect of moisture content?
	Anchorage in thin APC panels constructed of UHPC	
	Durability of textured finishes used for APC	
	Form suction for stripping APC with projections and rustications	
	Bond of brick, tile, and precast concrete medallions in APC	
	Post pour replacement techniques for brick, tile, and precast concrete medallions in APC	
Operations	Trucking of precast concrete members from manufacturing plants to job sites	Managing specialty carriers and non-standard sized loads to arrive at the crane at the correct time + or – 5 minutes
	Handling of steel reinforcing, connection plates and inserts is the majority of work done in the manufacturing plant.	Eliminating or drastically reducing non-value added materials handling work in the manufacturing plants. Robotic application for highly repetitive low skilled work? Impact of autonomous delivery vehicles?
	Improved ergonomics in work tasks of production employees	Reduced bending and stooping, lifting of heavy and awkward loads.
	Inspection of product, both finished goods and work in process, by electronic means	Utilize cameras, lasers or specialized AR or VR equipment to measure product vs. conventional steel tape. Compare to CAD drawings or 3D models for tolerances.

	Understand ability of current processes to meet tolerances, especially dimensional tolerances that affect fit-up and subsequently productivity on job sites.	Capture all variances from standard dimensions, not just go/no go based on adherence to published tolerances. Use data captured to calculate and publish process capability analysis.
	Machine learning / artificial intelligence / robotics	A general investigation into how these things might benefit our industry

*These topics also are on a list of research needs maintained by the ACI Concrete Research Council.

See: http://www.concreteresearchcouncil.org/Portals/7/Files/PDFs/Research_Needs.pdf