PCI Research Needs List November 2021

Category	Subject	Comments
Component Design and Detailing	Strength reduction factor for seismically confined columns	The compression-controlled phi factor for columns is 0.65. Spiral reinforced columns are given a higher factor of 0.75 due to improved confinement. The tied columns factor of 0.65 was based on #3 or #4 ties at roughly 16" o.c. wrapping every other leg. A seismically tied and confined column today has #5 ties at 4 inches o.c. This added confinement, for seismic ductility, provides much more reliable column capacity. A seismically confined column should have similar reliability to a spiral confined column. Investigate if a higher factor is justifiable in seismically confined (tied) columns.
	Inverted tee or spandrel beams that require more prestress than a plant can pull on beds/abutments	Methodology for strength and stresses for combined pretention (with strain compatibility) and unbonded post-tensioning (without strain compatibility)
	New cost-effective flooring system design that can be cast on long-line steel prestress beds	For total precast concrete building construction, develop alternative sections to double tees and hollowcore. Develop floor system conducive to receiving integral plumbing, HVAC piping and/or electrical conduit.
	Examine the longitudinal splitting strength of hollowcore slabs subject to line loads parallel to the span	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 hollowcore 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 need to be studied.
	Shear strength in end regions of pretensioned bridge components	Address anchorage of longitudinal reinforcement (tension tie) for reliable shear strength.

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Component Design and Detailing	Hangers for openings in hollowcore slab systems	Explore different hanger designs and effectiveness including support of reaction at adjacent members.
	Release stresses in pretensioned members	Consider all sections where compression and tension must be considered. Increase allowable compressive stress from 0.6 to 0.7 or 0.75. Determine minimum concrete strength requirements at release of prestressing.
	Improved detailing of double tee bearing plates	
	Headed deformed bars as shear reinforcement	
	Minimum spacing requirements for large prestressing strands	
Seismic	Improved diaphragm connection performance when subject to earthquake loading (**priority**)	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. Develop a ductile welded chord connector with high deformability.
	Refine Ω_v in ASCE 7-16 Diaphragm design (**priority**)	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. This is having a large impact on precast systems a more in-depth study is justified to refine or validate this factor.
	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 since 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

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Seismic	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.
	Connections at wall corners for Intermediate Precast Walls used for shear walls where there is a shear flow requirement to develop overturning resistance across a joint	Anchorage to concrete requirements in Section 17.10 of ACI 318 are excluded in plastic regions in the seismic force-resisting system. Steel yielding is required as the limit state for intermediate wall connections. Development and testing is needed.
	Seismic Design for wall panels with horizontal joints without minimum reinforcement 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
Structural Systems	Hybrid frame application to disproportionate collapse	Hybrid frames used for seismic resistance may have significant capacity for disproportionate collapse

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Anchorage to Concrete	Effects of reinforcement in concrete anchorage breakout zones (**priority**)	Anchorage reinforcement is allowed in Chapter 17 of ACI 318, but the provisions are limited to direct transfer of shear and tension forces in the direction of the load and require development of the reinforcement on either side of the breakout surface. There is a need to develop resistance to side-face breakout using shear friction reinforcement with development achieved by longitudinal reinforcement inside the bends of ties or hairpins.
	Replacement of headed anchors with headed reinforcement (**priority**)	Considerations for the replacement of headed concrete anchors welded to embed plates with headed reinforcement.
	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 $\boldsymbol{L_d}$ 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 $\boldsymbol{L_d}$ 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 $\boldsymbol{N_u}$ 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

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Wall Panels	Crack mitigation for insulated panels with continuous insulation	Insulated wall panels with thin wythes tend to crack during detensioning. Develop alternative details, materials, or criteria to minimize cracking.
	Effect of reinforcement to improve edge lifting devices in thin panels	
Handling and Erection	Productivity in the field	More efficient connections to replace welding 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.
Materials	Cement replacement in concrete mixes (**priority**)	Investigate alternative cementitious materials or carbon sequestration materials to reduce embodied carbon in precast elements. Note that most precast elements require high-early strength concrete mixtures to facilitate prestress release or stripping and handling.
	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.
	Provisions for concrete strengths less than UHPC	An ongoing research project is defining a PCI-UHPC with a compressive strength of 18ksi along with flexural strength around 2ksi and other tensile property requirements. Determine procedures for concrete strengths that develop flexural strengths higher than conventional concrete, along with tensile ductility, but do not meet PCI-UHPC criteria.
	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
	Structural design guidelines for sand lightweight concrete	

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Materials	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
	Effects of elevated temperatures from fire on fiber reinforcement and FRP composites in precast concrete structural members	
Sustainability	Life-cycle costs for pretensioned concrete bridges (**priority**)	Limited information is available on life-cycle assessments for pretensioned concrete bridges. A comparison of life-cycle costs for pretensioned concrete bridges to other typical bridge systems, in particular simple- and short-span bridges is needed.
	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	
3D Printing	Feasibility of pre-printed concrete components in plant	Precast producers have experience with handling, shipping, and erection. 3D printed concrete elements can have infinite shapes. Evaluate the feasibility of "pre-printed" (3D printed in a precast plant) elements and the type of structural components that can be achieved.

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Architectural	Effect of moisture content on APC color	Architectural panel color can be judged at many different ages. What is the effect of moisture content?
	Post pour replacement techniques for brick, tile, and precast concrete medallions in APC	
	Form suction for stripping APC with projections and rustications	
	Bond of brick, tile, and precast concrete medallions in APC	
	Anchorage in thin APC panels constructed of UHPC	
	Durability of textured finishes used for 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