



APPENDIX C

List of Concrete/Cement and Asphalt LCTMs

Category	Topic	Process or Technology	Description	Schedule Impact	Cost Impact	Site Impact	Project Type	Initiating Entity	Timeline	Comments
Carbon Dioxide Supplemented Mixtures	Sequestering of waste Carbon Dioxide	Injection of waste carbon dioxide into concrete mixture	Sequestering industry waste carbon dioxide through an injection process into a concrete mixture while lowering a mixtures cement content reducing the carbon footprint	None	No Change	No Impact	City Funded Only	Agency / Supplier	Tier 1 (Immediate)	Currently replacing 5.5% cement, would look to remove a maximum cement replacement threshold allowing suppliers the flexibility to achieve higher replacement values with the use of admixtures or
Optimized Mix Designs	Aggregate Optimization	Combining different aggregates to obtain a dense graded composition	Dense graded mix designs require less cement to achieve similar results reducing the mixtures carbon footprint	None	Slightly More	No Impact	All Projects	Supplier	Tier 1 (Immediate)	Industry needs to step up and investigate this as an option. Some smaller plants could have issues with silo or bin storage space that may limit their ability to
Industry	Increased Admixture Use	Implement the use of existing and new admixtures to reduce the amount of cement required	Set accelerating and hydration admixtures may be able to produce more thorough hydration of the cement allowing for a reduction in the standard content required	None	Slightly More	No Impact	All Projects	Agency / Supplier	Tier 1 (Immediate)	Depends on available admixtures, cost, and suppliers capacity to hold the additional products as well as the Agency allowing a reducing in cement content
Supplemental Cementitious Materials	Increase FDM's	Create new mix designs with increased FDM content	FDM's > 35%	Minor (5% - 10%)	Slightly Less	Extended Early Set Times	City Funded Only	Agency / Supplier	Tier 2 (1 - 2 yrs)	Agency would need to develop a policy or special provision, and suppliers would need to submit new mix designs which would likely require trials, also allow the use of FDM's with heated mix water
Supplemental Cementitious Materials	Ternary Mixtures	Utilize three cementitious components to achieve a 35% cement replacement target	Include two FDM's as partial replacement of cement content	Little to None (Less than 5%)	No Change	Extended Early Set Times	All Projects	Supplier	Tier 2 (1 - 2 yrs)	If the cement replacement is at 35% the process can be immediate as this replacement threshold is already allowed by IDOT's SSRBC
Optimized Mix Designs	Application Based Mix Designs	Create mix designs for the specific application	Create mix designs with strength requirements that are application based resulting in lower cement contents for items like sidewalks, curb and gutter, etc.	Minor (5% - 10%)	Slightly Less	Extended Early Set Times	City Funded Only	Agency / Supplier	Tier 2 (1 - 2 yrs)	Agency would need to develop a policy or special provision allowing reduced cement contents for specific items of construction and suppliers would need to create the mix designs
Industry	Component Ingredient Delivery	Use local sources to limit delivery generated carbon dioxide	Local materials are closer and require less haul distances resulting in reduced carbon dioxide from the delivery process	None	Slightly More	No Impact	All Projects	Supplier	Tier 2 (1 - 2 yrs)	The shorter the delivery distance the less fossil fuels it takes to deliver component ingredient creating a concrete product with a smaller footprint
Maintenance	Aggressive Deicing Chemicals	Reduce the use of aggressive deicing chemicals or use alternative products	Aggressive deicing chemicals attack the integrity of the concrete and any reinforcement within the concrete shortening its life-cycle require more frequent replacements	None	No Change	No Impact	All Projects	Local Agency	Tier 2 (1 - 2 yrs)	Current deicing chemicals are aggressive products that penetrate the concrete and cause damage to internal reinforcement and the matrix of the concrete creating distresses that result in shorter service life
Documentation	EPD's	Environmental Product Declaration	Quantifies carbon impact/reduction	None	No Change	No Impact	All Projects	Agency / Supplier	Tier 2 (1 - 2 yrs)	Not really a low carbon technology, just a mechanism to show a products carbon footprint
Workmanship	Construction Practices	Consistent practices that improve or realize the full potential of the concrete mix design	Avoid unrealistic construction timelines, proper subbase and subgrade preparation, proper placement techniques, and placement during favorable weather conditions	Moderate (11% - 20%)	Slightly More	No Impact	All Projects	Local Agency	Tier 3 (2 - 3 yrs)	Limit short contract completion timelines, poor subbase or subgrade preparation, and poor placement conditions during unfavorable weather to achieve an increased concrete life-cycle avoiding more frequent replacement reducing the amount of cement utilized over time and reducing the carbon footprint
Workmanship	Institute Winter Shut-down	Build into the construction schedule winter shut-downs	Establishing a known construction season outside of winter ensures conditions are favorable for placing and curing concrete	Extensive (More than 20%)	Moderately More	No Impact	All Projects	Local Agency	Tier 3 (2 - 3 yrs)	Concrete placed during favorable conditions will have better durability and life-cycles resulting in less demand on cement over time reducing the City's carbon footprint
Supplemental Cementitious Materials	Increased Slag Cement with C-S-H Seeding	Implement C-S-H seeding technology	Increases initial strength results	None	Moderately More	Curing Concerns	City Funded Only	Industry / Academia	Tier 3 (2 - 3 yrs)	Further development needed and increased availability before considering any trials. Michigan State started RMRC (Recycled Materials Research Center) which could be an avenue to get this and other experimental options trialed
Industry	Calcined Clay Cements	A clay cement product as a replacement to cement	Specialty cement with up to 50% less CO ₂ generated during the cement production process	None	Moderately More	Supply / Availability Concerns	City Funded Only	Industry / Academia	Tier 4 (3 - 4 yrs)	Possible option further down the road
Optimized Mix Designs	AI driven Mix Designs	Mix designs created with AI assistance	Mix design options generated using AI to optimize a mix design for specific application requirements reducing the need to perform multiple laboratory trials	None	Undetermined	Extended Early Set Times Curing Concerns	Undetermined	Agency / Supplier	Tier 4 (3 - 4 yrs)	This technology is under development and trials, no clear understanding of how close this technology is to wide spread deployment
Industry	Alternative Recycled Components	Recycled aggregates or cementitious materials.	Recycled component products reduce carbon on the component production side of the process	Little to None (Less than 5%)	Slightly Less	Supply / Availability Concerns Extended Early Set Times	City Funded Only	Industry / Academia	Tier 4 (3 - 4 yrs)	New recycled opportunities are being researched and could provide reductions in carbon dioxide output



CDOT LOW CARBON CONCRETE OPTIONS



Category	Topic	Process or Technology	Description	Schedule Impact	Cost Impact	Site Impact	Project Type	Initiating Entity	Timeline	Comments
Mixture and Design Properties	Innovative Reinforcements	Fibers and Fiberglass Reinforcement Bars	Use of fiberglass reinforcement bars would eliminate corrosion and expansion of the steel limiting concrete degradation, and fibers could keep concrete together longer, both products could extend the life of the concrete.	Minor (5% - 10%)	Moderately More	Aesthetic Concerns Placement Concerns	Undetermined	Agency / Supplier	Tier 4 (3 - 4 yrs)	These products have been available, just not sure to what extent they have been tried and shown to be successful in transportation concrete infrastructure work
Industry/Academia	Alternative Cement Production Processes and CO ₂ Capture and Reuse	Improve the efficiency of producing cement and/or capture of the CO ₂ produced during cement production and use in other industry processes	Universities are researching alternative production process for cement and ways to capture and reuse the CO ₂ generated during cement production	None	Slightly More	No Impact	Undetermined	Industry / Academia	Tier 5 (4+ yrs)	Future advances for consideration
Academia	C-Crete	A non-cement binder	Currently in research and development, has similar mixing requirements and aggregate proportions with no high temperatures required during production	Undetermined	Undetermined	Undetermined	Undetermined	Academia	Tier 5 (4+ yrs)	Future advances for consideration
Mixture and Design Properties	Perpetual Pavement	Pavement design mechanism	Lower pcc base section that isn't exposed to stresses large enough to create deterioration, allowing for a renewable surface while retaining the base pcc layer	Undetermined	Undetermined	Undetermined	Undetermined	Academia	Tier 5 (4+ yrs)	Not sure of any research into this concept, more of a brainstorming idea. This type of concept is currently available in the HMA industry

CDOT LOW CARBON ASPHALT PAVEMENT OPTIONS

Category	Topic	Process or Technology	Description	Anticipated Cost To City	Allowable Project Type	Action Required by	Timeline	Comments
Increased Recycled Content	Increased Asphalt Binder Replacement (ABR)	Recycled Asphalt Pavement Replacement for Virgin Aggregates and Asphalt Binder	Increase ABR 20% for all mixture classes	Decreased Cost	All Projects	Agency/Supplier	Unknown (3+ yrs)	Agency would need to develop a policy or special provision, and suppliers would need to submit new mix designs which would likely require trials, also allow the use of increased ABR mixtures.
Decreased Production Energy Use	Warm Mix Asphalt (WMA)	Decreased mixture production temperatures resulting in fuel savings for lower energy consumption.	Utilizing WMA admixtures to reduce mix production and compaction temperatures extending compaction window.	Undetermined	All Projects	Agency/Supplier	Unknown (3+ yrs)	The addition of WMA admixtures results in decreased mixture temperatures reducing production energy usage and allows for an increased compaction window.
Mixture Components	Increased Local Aggregate Source Use	Using locally available aggregates.	Locally sourced aggregates reduce transportation distance reducing CO ₂ foot-print.	Decreased Cost	All Projects	Agency/Supplier	Unknown (3+ yrs)	Locally sourced aggregates for use in specialty mixtures like stone matrix asphalt reduce fuel consumption during transportation of aggregate components.
Mix Design Classes	Increased Life-Cycle Designs	Utilizing more stone matrix asphalt mix designs with highly polymerized asphalt binders.	Higher type mixtures with more durable component ingredients increase life-cycle of pavement.	Increased Cost	All Projects	Agency/Supplier	Unknown (3+ yrs)	Utilizing high type mixtures improve pavement performance resulting in fewer maintenance operations and longer service life.
Smart Technologies	Intelligent Compaction	Roller mapping, dielectric density testing to ensure continuous optimum pavement compaction.	Utilize compaction technologies to ensure complete compaction maximizing pavement service life.	Undetermined	All Projects	Agency/Supplier	Unknown (3+ yrs)	Continuous compaction technologies ensure the entire pavement is compacted compared to localized random verification testing (cores/nuclear tests).