Performance Concrete Optimized for Cost, Durability, Manufacturability and Sustainability

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Project Statement

Concrete is the backbone of transportation pavement and infrastructure, providing strength, durability, and safety. Meeting the performance targets outlined in specifications is crucial for ensuring the long-term success of construction projects. However, delays in obtaining approval for mix designs can hinder progress and escalate costs for regional concrete producers. This project aims to address this challenge by developing a generic mix design for Performance-Based Concrete that meets the performance specifications set by the Vermont Agency of Transportation. This generic concrete mix will be optimized to reduce cost and increase durability by employing the maximum packing density technique on locally sourced aggregates and partially replacing cement with supplementary cementitious materials.

Objectives

Develop generic prescriptive concrete mixes that are cost effective, more durable, sustainable using local aggregates, achieved through these tasks.

- Optimization of aggregate skeleton
- Optimization of binder composition
- Comparison of different shrinkage mitigation strategies
- Development of new concrete mixes using optimized binder compositions, optimized aggregate skeleton, and selected shrinkage mitigation strategies

https://myrenovationspecialist.com/concrete-failure/ https://pozzotive.com/product-benefits

Fig 1: Poorly packed aggregates (left), well-packed aggregate with maximum packing density (middle) and SCM's as partial replacement of cement, e.g. Ground glass pozzolan, Flyash, etc

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Results

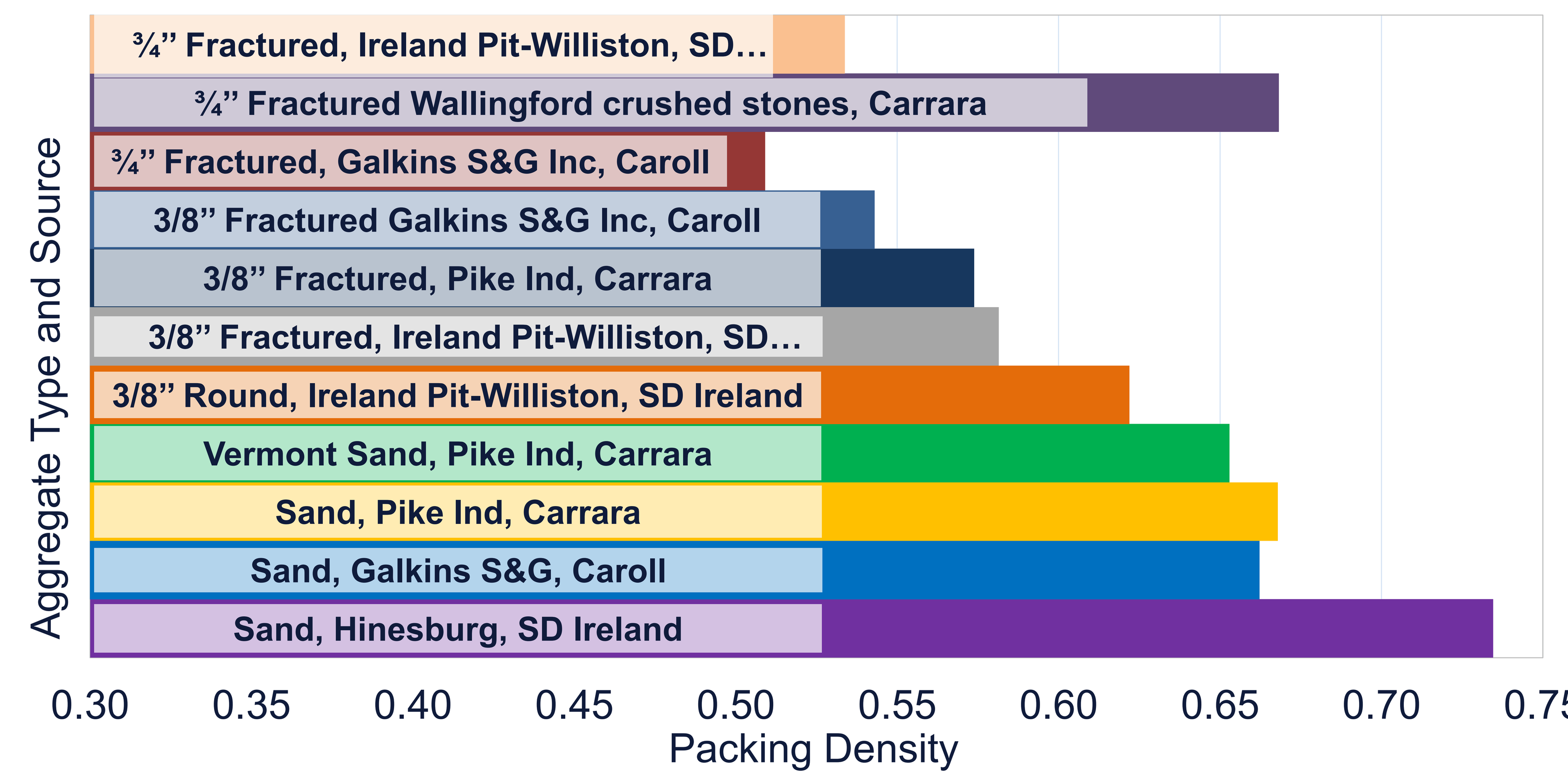
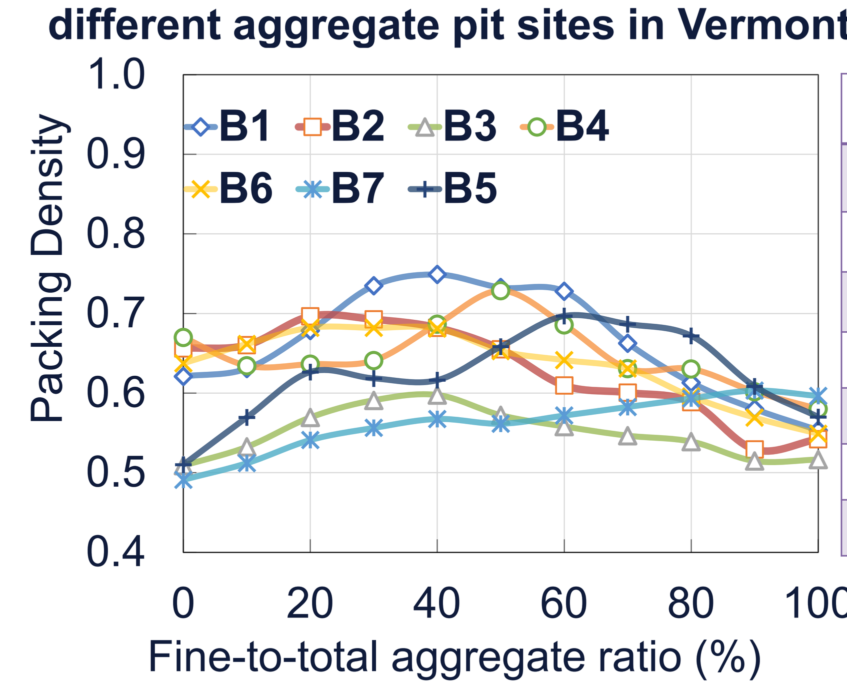


Fig 2. Packing density of individual fine and coarse aggregates sourced from different aggregate pit sites in Vermont.



	Aggregate 1	Aggregate 2
B1	3/4" stones, SD Ireland	Sand, SD Ireland
B2	3/4" stones, Carrara	Vermont Sand, Carrara
B3	3/4" Stones, Caroll	Sand, Galkins
B4	¾" Stones, Carrara	3/8" Stones SD Ireland
B5	3/8" Stones, Carrara	3/4" Stones, Caroll
B6	¾" Stones, Carrara	Sand, Carrara
B7	¾" Stones, Caroll	3/8" R. stones, SD Ireland

Fig 3. Packing density values of locally sourced binary aggregates

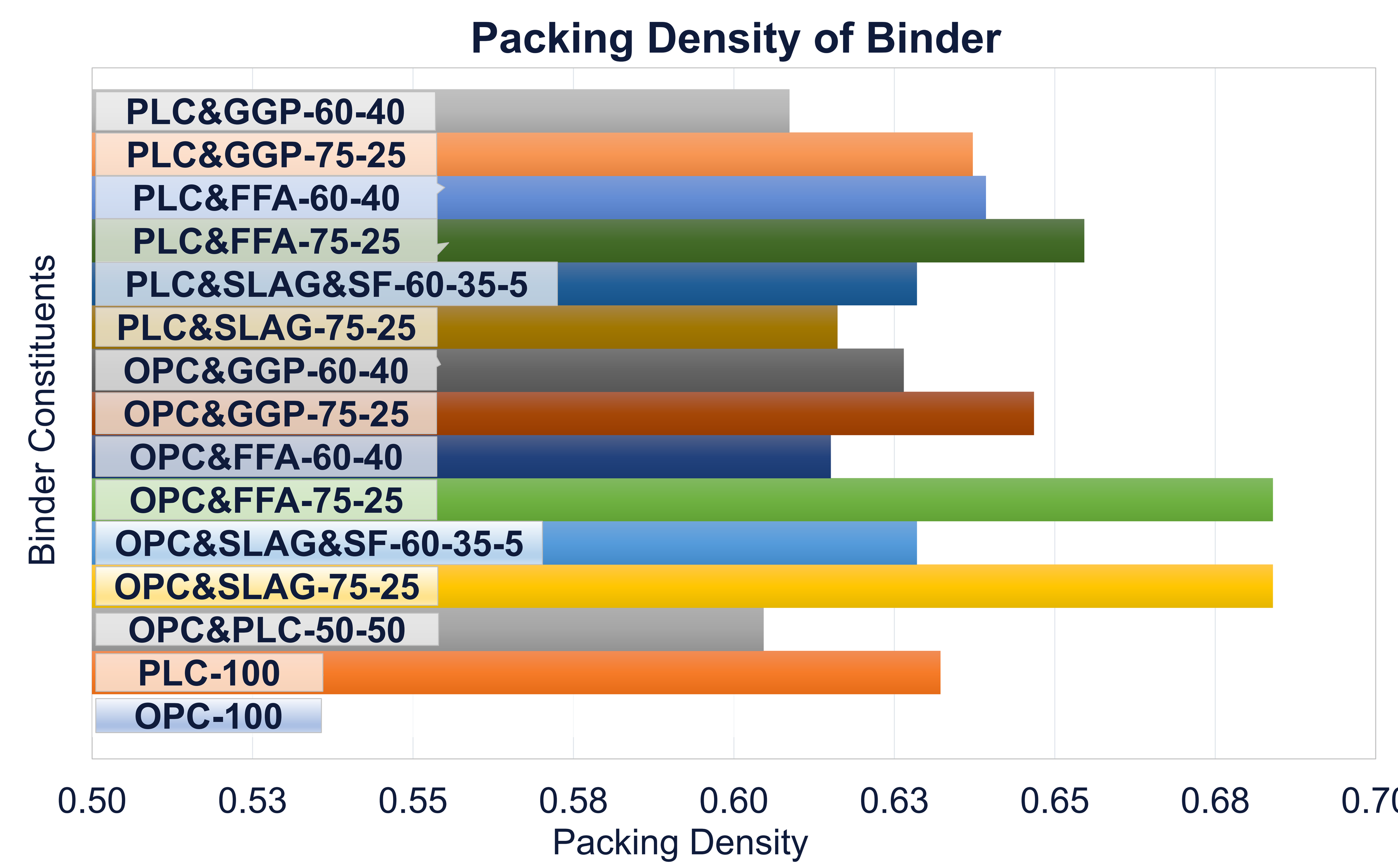


Fig 4. Packing density values individual, binary and ternary cement blends.

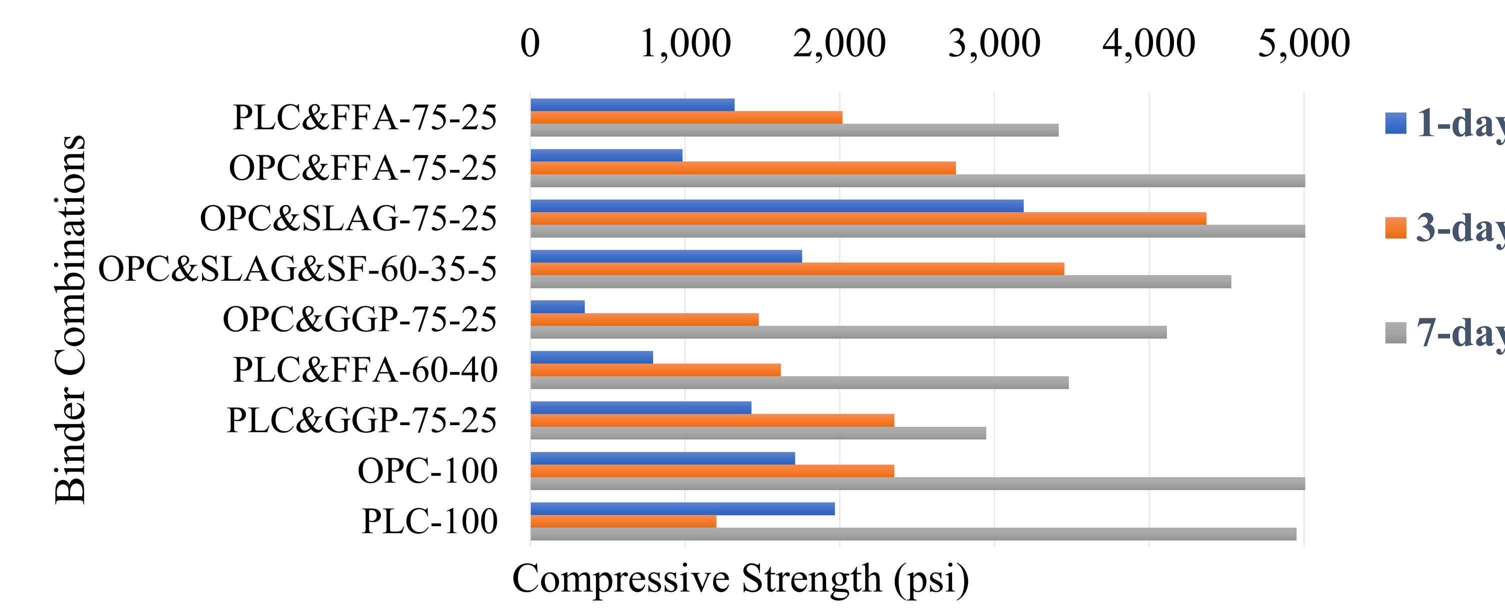


Fig 5. Compressive Strength Development of Binder Compositions

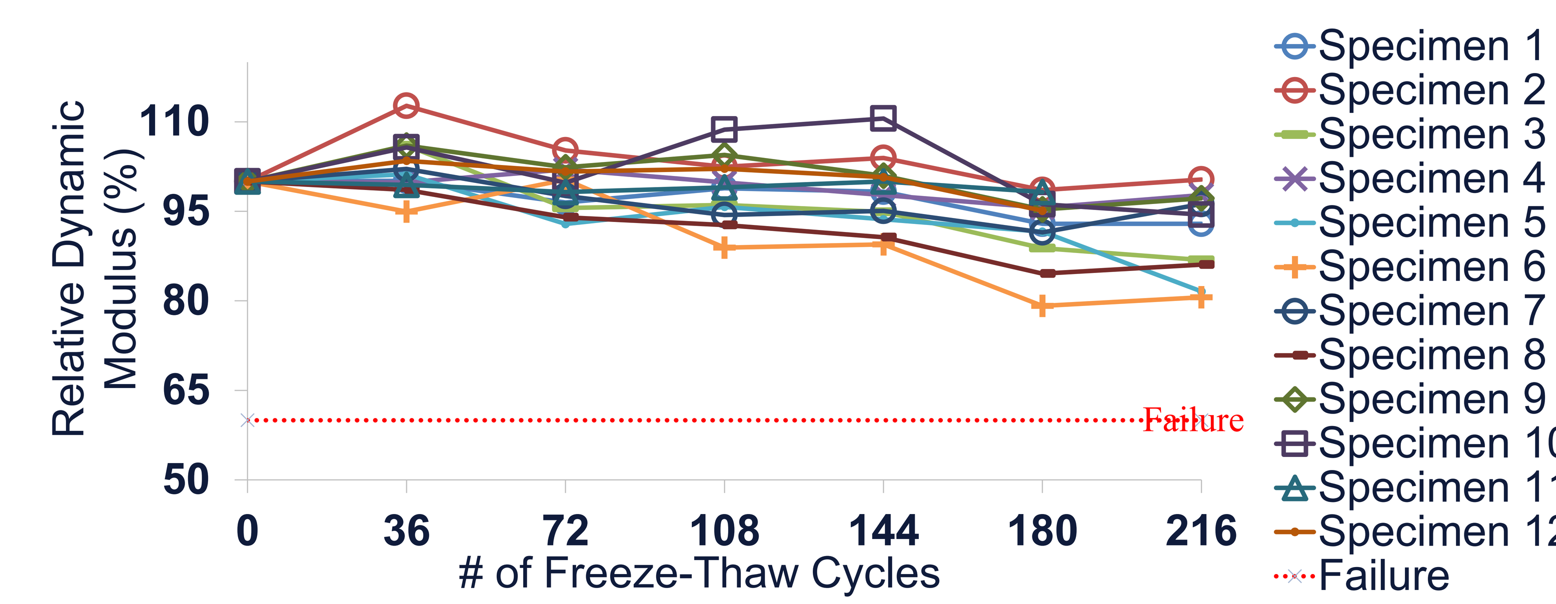


Fig 6. Shows the relative dynamic modulus of specimens made from initial concrete mixes which depicts the gradual deterioration of the specimens during the freeze thaw tests.

Upcoming work

- Evaluate the efficacy of various shrinkage mitigating strategies and selecting the top two performing approaches
- Develop several performance-based concrete mixes and test them against these selected performance parameters:
  - **Workability**: Slump, spread, VSI, Air content, Unit weight
  - **Mechanical properties**: Compressive strength, Flexural strength, and Modulus of elasticity.
  - **Durability**: Freeze-thaw, Abrasion, and Surface resistivity
  - **Shrinkage and cracking**: Autogenous and drying shrinkage

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