Integrating Additive Manufacturing with Accelerated Bridge Construction Techniques

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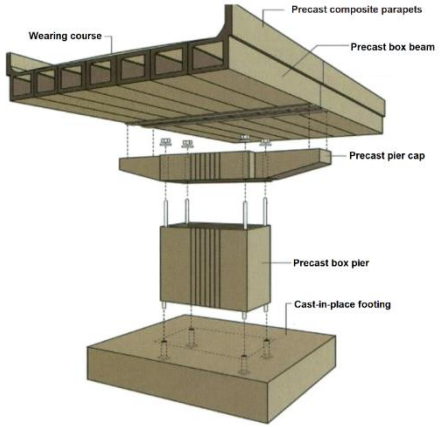
The Problem

Modular forms of bridge construction have been of continued interest in prefabricated bridge elements and systems (**PBES**)

The Limitations:

- High cost for developing modular forms
- Time consuming and labor intensive
- Construction safety concerns
- Limited customizability



The Needs:

Increase the construction quality of PBES

Reduce their construction time and labor cost

Enhance the safety and reliability

Minimize the environmental footprint of the PBES fabrication plants

Produce structural elements with optimized topologies

Enable in-situ repair of existing ABC elements via customizable design

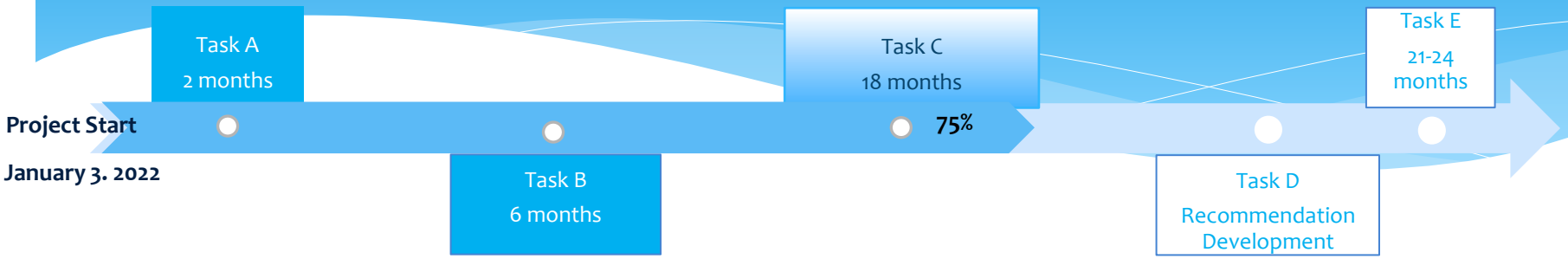
Project Objectives

- Explore the feasibility of integrating additive manufacturing with ABC techniques in Pennsylvania
- Identifying, fabricating and mechanical testing of a range of 3D printable prefabricated bridge elements currently used in ABC projects

Project Approach

- 3D Concrete Printing (3DCP).
- Control group for casted beam with/without rebar beam, 3DCP formwork with/without rebar beam, fully printed with/without rebar beam, and fully printed with staples.
- 3-point bending test to compare the max stress.
- Prefabricated small-scale ABC elements

Schedule/Status

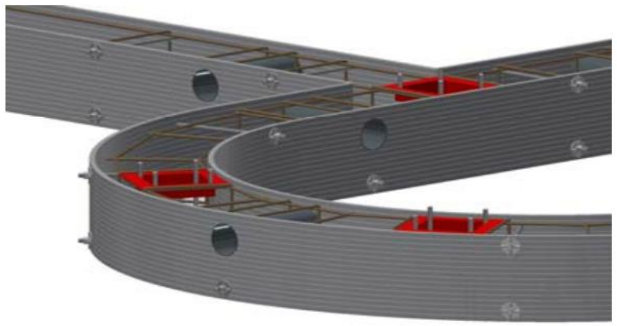


- ☑ Task A – Review of the stat-of-the-art of 3D concrete printing research
- ☑ Task B – Identifying optimal 3DCP reinforcement and mixture designs for bridge prefabricated elements
- **Task C – 3D printing of prefabricated elements in ABC systems at small-scale**
- Task D: Development of Recommendations
- Task E: Final Report

Task A-Review of Mixture and Reinforcement Strategies

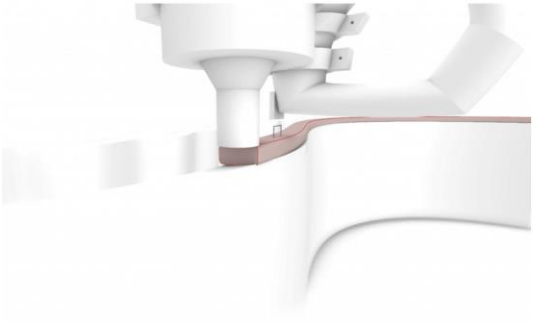
Placing steel reinforcement horizontally between 3d-printed concrete layers

Concrete floor slabs with add-on-printed reinforced ribs

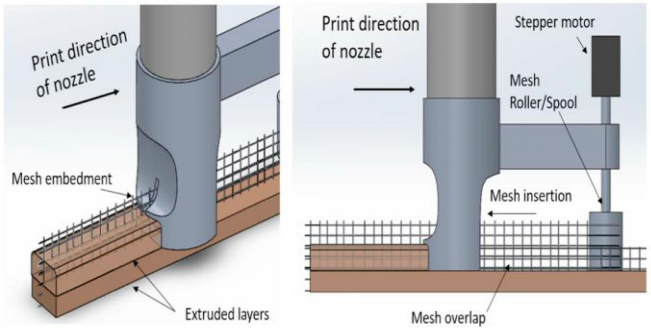


Placing vertical reinforcement in 3D printed formwork which will be filled with flowable or vibrated concrete

Post-tensioning of steel reinforcement placed in 3D printed conduits



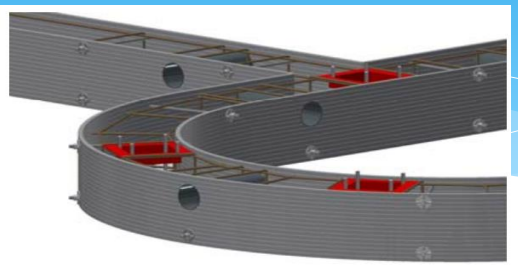
Staple reinforcement while printing. Use staple guns and large size staples for reinforcement



Mesh insertion and embedment using the custom-designed 3D printing nozzle

Task B-Reinforcement Selection

Place rebar while printing



Place rebar in printed formwork

Place steel rope while printing

#3 rebar is selected

1-5/8 in staple is selected

Task B-Beam Sample Fabrication

Without Reinforcement

Printed Formwork

Printed Entire Sample

With Reinforcement

Printed Formwork with Reinforcement

Printed Entire Sample with Reinforcement

Task B-Beam Sample Fabrication

Without Reinforcement

Printed Studs Formwork

With Reinforcement

Printed Studs Formwork with Reinforcement

Printed Entire Sample with Staples

Task B-Beam Sample Test

Without Reinforcement

Cast

Printed Entire Sample

Printed Formwork

Task B-Beam Sample Test

With Reinforcement

Cast with Reinforcement

Printed Formwork with Reinforcement

Task B-Beam Sample Test

Task B-Beam Sample Test Results

Casted		
Beam Width	6	In
Beam Height	6	In
Max Load	5.17	kips
Max Stress	646.3	psi

3DP-Formwork		
Beam Width	8	In
Beam Height	6	In
Max Load	4.20	kips
Max Stress	393.5	psi

3DP-Formwork-Studs		
Beam Width	8	In
Beam Height	7	In
Max Load	4.82	kips
Max Stress	331.7	psi

Fully 3DP		
Beam Width	8	In
Beam Height	6	In
Max Load	8.26	kips
Max Stress	774.3	psi

Casted-Rebar		
Beam Width	6	In
Beam Height	6	In
Max Load	13.64	kips
Max Stress	1704.9	psi

3DP-Formwork-Rebar		
Beam Width	9.5	In
Beam Height	6	In
Max Load	19.63	kips
Max Stress	1549.4	psi

3DP-Formwork-Studs-Rebar		
Beam Width	7	In
Beam Height	7	In
Max Load	29.46	kips
Max Stress	2319.04	psi

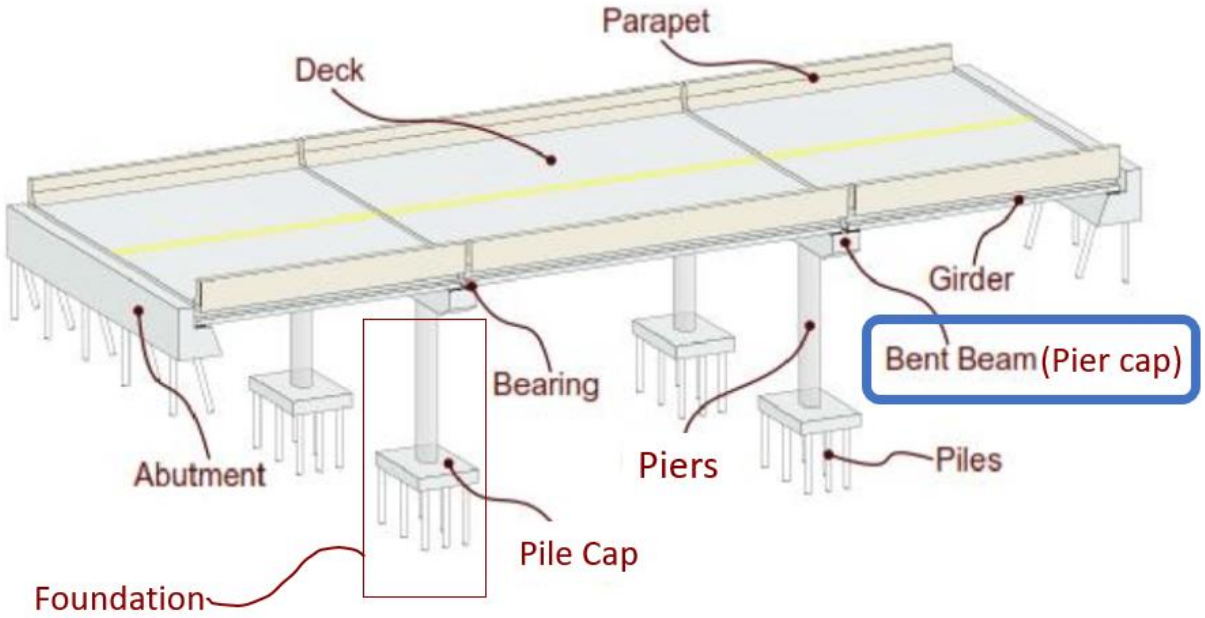
Fully 3DP-Rebar		
Beam Width	10	In
Beam Height	7	In
Max Load	34.06	kips
Max Stress	1876.6	psi

3DP-Stapling		
Beam Width	8	In
Beam Height	6	In
Max Load	5.07	kips
Max Stress	474.94	psi

Task C-Main Bridge Components Review and Selection

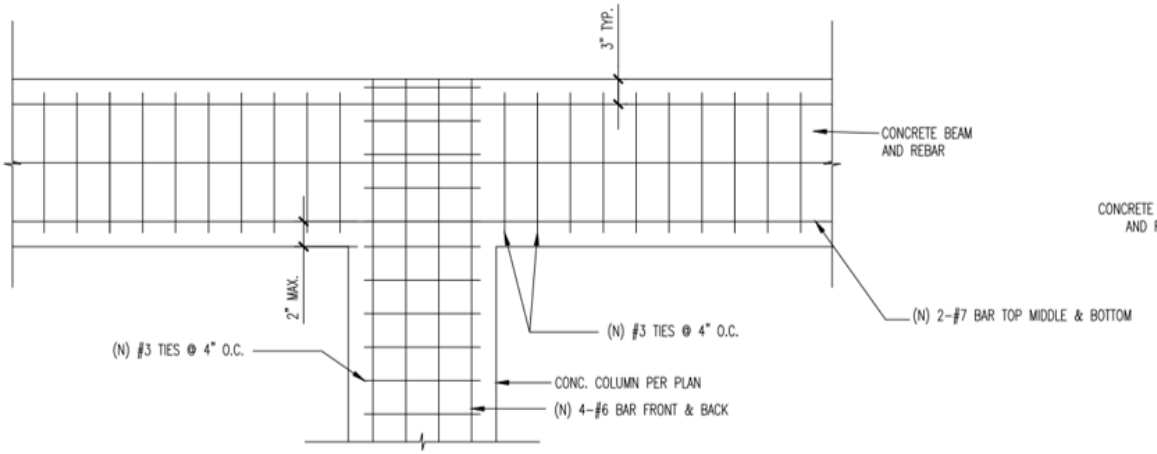
Main Components:

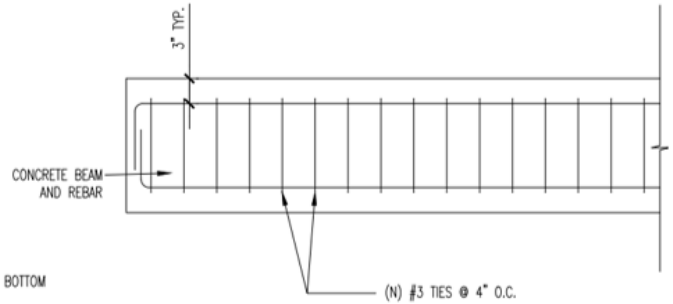
- **Abutment**
- **Girder**
- **Bent Beam**
- **Piers**

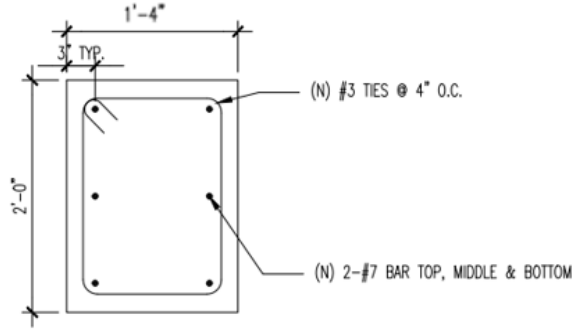


Final Decision: Pier cap

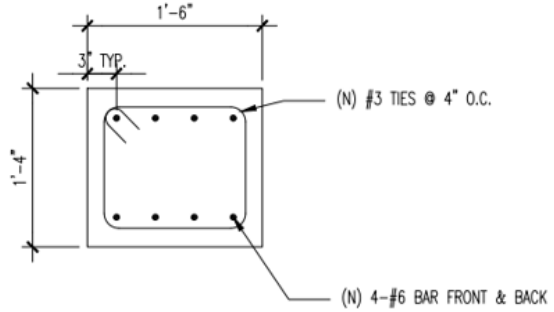
Task C-Pier Cap Design Detail





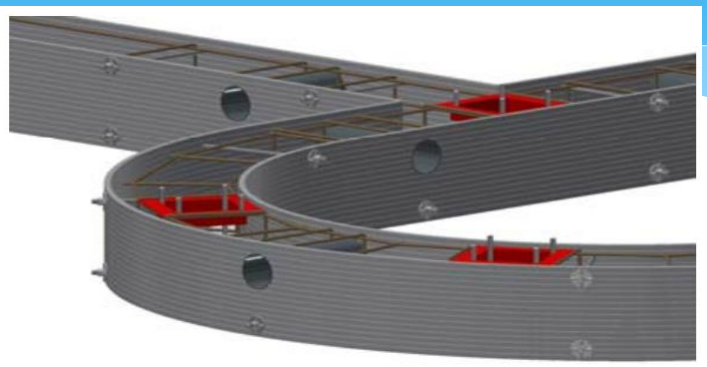


CONC. BEAM CROSS SECTION



CONC. COL. CROSS SECTION

Task C-Reinforcement Selection



Place rebar or staple while printing or printed formwork

Double-loop twist ties is selected for typing rebar

#3 #6 and #7 rebar is selected

Wood board & contact lumber is selected for casted

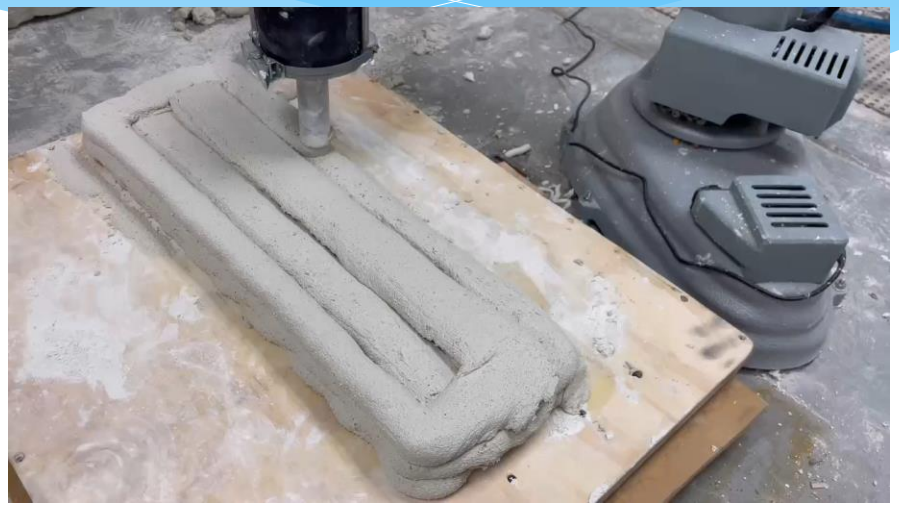
Task C-Work Planned and Challenges

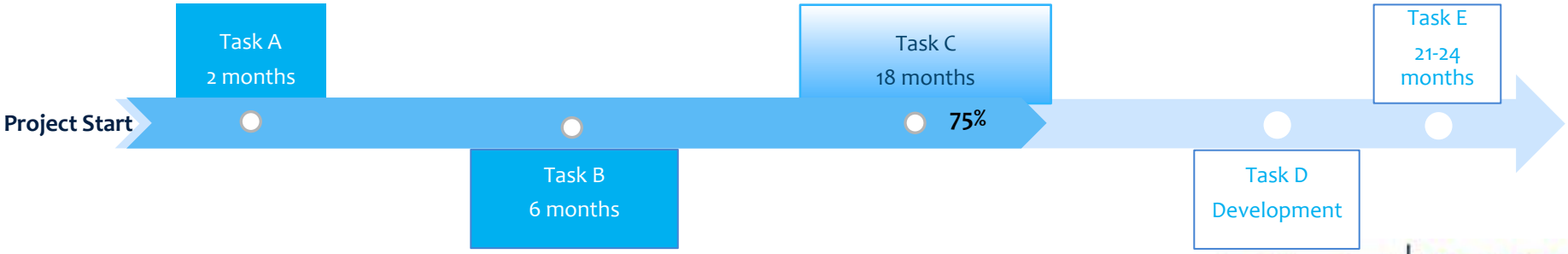
Next Step:

- Printing Formwork with Rebar Sample
- Casted with Rebar Sample
- Test samples

Challenges:

- Printing Speed Tuning
- Pumping Speed Tuning
- Reinforced Cage Fabricate
- Wood Cage Fabricate
- Embedded Method





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Thank you

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