NEW ENGLAND TRANSPORTATION CONSORTIUM
RESEARCH PROBLEM STATEMENT FORMAT

Due to netc@ctcandassociates.com by January 24, 2020

I. PROBLEM TITLE

Large-Scale Additive Manufacturing (3D Printing) for Enhanced Infrastructure

II. RESEARCH PROBLEM STATEMENT

Clearly define the problem and provide sufficient evidence to support its importance to the New England region. The statement should discuss the gaps in current knowledge, literature, and studies that demonstrate the research need.

Additive manufacturing or 3D printing is being touted as a transformation technology in the transportation industry. This claim rests largely with the ability to design and manufacture custom parts without the need of stockpiling in warehouses. This technology also dramatically reduces the need to transport freight long distances since a product can be printed closer to the end users.

Recent advances in large-scale 3D printing and thermoplastic composite materials with bio-based fillers and reinforcements have great potential for expanding the possibilities of making forms for precast concrete structures. The Precast/Prestressed Concrete Institute (PCI) has a partnership with Oak Ridge National Lab from the Department of Energy (which is the leading organization in the US in additive manufacturing) to develop 3D printed molds for precast concrete applications.

PCI has also reported that precasters cannot replace retiring skilled labor (carpenters) for making complex molds and formwork. The 3D printing technology uses computer design and automation skills, which are prevalent with the new workforce generation and, therefore, can fill the gaps of skilled labor for making complex molds and forms. For this reason, the 3D printing technology for making molds, forms and tooling for precast concrete is expected to reduce labor cost. Additionally, the 3D printed mold becomes an asset, since thermoplastic composite materials can be reprocessed. It is important to understand how the material can be reused and how this can contribute to cost reduction.

Currently, there are efforts in Maine to design and fabricate a 54 ft long 3D printed mold for the precast concrete pier cap of the Ohio Street bridge replacement project over I-95 in Bangor, ME. The project involves geometric design of the mold with locking and aligning mechanism, selection of suitable bio-based material, surface finishing (milling) and structural analysis of the formwork to ensure stiffness and strength required for concrete casting.

Currently, there are three large-scale 3D printer models that are commercially available in the US: 1) Big Area Additive Manufacturing (BAAM) from Cincinnati Inc., 2) Large Scale Additive Manufacturing (LSAM) from Thermwood Corp., and 3) MasterPrint from Ingersoll Machine Tools.

Despite some of these efforts, there is still no clear direction on the best alternatives for the infrastructure nor are there any standard procedures or processes to enable the acceptance of 3D printed components for DOT's. These questions need to be thoroughly addressed: Which applications will be cost effective, reduce costs and/or improve durability and can be implemented at the state DOT level?

III. RESEARCH OBJECTIVES

Define specific research objectives. These may be more specific than the broad need described in Section II. These should be project objectives (expected results) and not tasks or methodology.

The overall objective is to develop a procedure for designing and manufacturing 3D printed parts for applications in transportation. Specifically, the project will:

a) Identify products such as complex formwork shapes and other bridge components that have potential to reduce the cost.
b) Select material alternatives that would be suitable for large-scale 3D printing
c) Develop specifications
d) Potentially demonstrate 3D printed materials on DOT project(s)

The specifications will include: material performance requirements (strength, stiffness, dimensional stability and durability), fabrication tolerances, open-source design software, interface with commercial software for developing the tool path (slicer), requirements for surface finishing (milling), recyclability, and repair methods.

Understanding what defects or flaws are introduced by a particular 3D printer and how these defects can grow under stress and strain during service of the part (cyclic and/or sustained loads) is required to predict durability. The performance of thermoplastic composite materials, which are cost effective and durable for large-scale 3d printing, such as ABS/carbon fiber and PLA/wood fillers, will be evaluated as part of the project.

This project will develop a high priority list of implementable products for transportation infrastructure, select one of the products, produce the product and test on project(s) throughout New England.

The project will educate stakeholders on additive manufacturing, including limitations, available technologies and materials.

It is essential for this project to have an active role interacting with industry and national organizations to identify opportunities and implement recommended practices for large-scale additive manufacturing in infrastructure. The project requires outreach to the New England DOTs, regional precasters and relevant technical committee(s) of PCI.

IV. COST ESTIMATE

An estimate of the funds necessary to accomplish the objectives described in Section III.

$175,000

V. RESEARCH PERIOD

An estimate of the number of months necessary to complete the research. In addition, include preparation of a Draft and Final Report and its review by the NETC project Technical Committee (90 days).

The project duration will be 24 months.

VI. URGENCY AND PAYOFF POTENTIAL

A description of the urgency of the need for this research in relation to the transportation needs of the six New England States. A discussion of the potential benefits to be derived from the anticipated research results i.e., time/cost savings, enhanced practice/performance, improved safety, other.

The main deliverable of this project to the New England DOTs will be to demonstrate the feasibility of implementing 3D printed products to lower the cost of bridge components. This will be done by developing standard procedures and specifications and by implementation of 3D printed materials on DOT project(s).

This will enable the DOT's to take advantage of this technology potentially leading to time savings, improved durability and cost savings.

VII. IMPLEMENTATION POTENTIAL

To aid NETC in deciding whether to fund this project, describe:

- *The intended DOT audience(s) for using the research products.*
- *Type of implementation anticipated as a result of the project (i.e. confirm existing, adopt new or eliminate current standards, specifications, processes, policies, regulations or drawings, GIS application).*
- *Activities to facilitate implementation (e.g. brochures, posters, exhibits at conferences, tech sheet summaries, webinars, presentations, training workshops, peer exchanges, pilot or demonstration project at host agency) to help create awareness and facilitate implementation of the research results.*
- *Anticipated barriers or constraints to implementation and ways to overcome them.*
- *Methods of tracking and measuring the impacts of implementation.*

The DOTs will have a standard and validated process for procuring 3D printed products that will minimize the effort of testing multiple parts for new transportation applications. For example, if a precast manufacturer requests to use 3D printed formwork, current DOT specifications do not address this usage. The DOT's will need assurance that the 3D printed forms will meet or exceed strength, durability and surface finish requirements and will not be detrimental to the final product. Having certified 3D printing manufacturers and a process to follow will enable usage of products from this technology on our projects.

The results of this work will be used by DOT fabrication engineers, inspectors and others that are responsible for ensuring bridge components meet specifications.

The DOTs will have a process for procuring 3D printed products that will meet dimensional tolerances and surface finishing requirements at low cost.

The project findings will be disseminated in conferences and publications.

TWO DOT STAFF ENDORSEMENTS ARE REQUIRED (To be signed by separate individuals.)

VIII. ENDORSEMENT BY THE SPONSORING DOT REPRESENTATIVE TO THE NETC ADVISORY COMMITTEE

By signing the endorsement, the DOT representative is certifying that:

1. *The Problem Statement follows the required format.*
2. *The Problem Statement addresses a transportation issue of relevance to NETC and does not duplicate another Problem Statement being submitted at this time.*

_Dale Peabody_________________________________ _Maine____________
Name DOT

__Dale Peabody__________________________ __1/24/2020_________________
Signature Date

ENDORSEMENT BY THE SPONSORING DOT PROBLEM STATEMENT AUTHOR/SUBMITTER

By signing the endorsement, the DOT Problem Statement author/submitter is certifying that:

1. *I have technical knowledge of the project topic and will be committed to the research outcome.*
2. *I agree to serve as Chair of the project's Technical Committee if this Research Problem Statement is selected for funding by NETC.*

_Joseph Stilwell__________________________________ ___Maine________________
Name DOT

_Joseph Stilwell_______________________________ __1/24/2020__________
Signature* Date
*Attached email/correspondence may substitute signature

NOTE: To expedite the processing of Research Problem Statements, NETC requires submittal by e-mail from signing Advisory Committee member to (netc@ctcandassociates.com) by January 24, 2020.