aci American Concrete Institute
Always advancing

aci Foundation
Building the Future

GUIDE FOR INNOVATORS

PUBLISHED BY THE

CONCRETE INNOVATION COUNCIL

---

www.acifoundation.org/technology

Introduction

The American Concrete Institute (ACI) and its subsidiary, the ACI Foundation, encourage the advancement of the concrete industry by finding and supporting innovations and new technologies. After evaluation by the ACI Foundation's Concrete Innovation Council (CIC), which is a panel comprising leading industry members, the ACI Foundation may help to advance an innovative technology by providing:

- Assessments and recommendations;
- Referrals to relevant industry organizations or contacts;
- Support through research funding; or
- Opportunities to promote the innovation at relevant events.

Recommendations may include proposals that ACI create a committee, educational products, or certification program. Referrals may involve other ACI subsidiaries.

How Can Industry Members Help?

Industry members can notify ACI and the ACI Foundation of needs, solutions, and technologies by emailing the ACI Director, Innovative Concrete Technology (innovation@concrete.org) or by contacting the Assistant Director of the ACI Foundation (https://www.acifoundation.org/home/contactus.aspx). These staff members will work with the CIC to assess the innovations and make recommendations for further actions to the Board of ACI and/or the Trustees of the ACI Foundation. To assist the staff members and the CIC, please provide the following information:

1. Product or process name;
2. Innovator contact information;
3. Category of innovation (for example, education and training, analysis and design, construction method, quality assurance, or materials);
4. Description of the relevant industry need;
5. Explanation of the innovation and how it will satisfy that need;
6. Self-assessment of the technology readiness level (TRL) (refer to Table 1); and
7. Description of the associated intellectual property (IP) protection (copyright, trademark, patent application number, or patent number) and ownership.

TABLE 1: *Descriptions of technology readiness levels (TRL) for innovations in science & engineering and software (After Fig. 2 in "Route-to-Market Guide for Innovators," Department of Research Contracts & Innovation, University of Cape Town, 2018, 32 pp.)*

TRL	1	2	3	4	5	6	7	8	9
Science & Engineering	Basic idea	Concept developed	Experimental proof of concept	Lab demonstration	Lab scale validation (early prototype)	Prototype demonstration	Capability validated on economic runs	Capability validated over range of parts	Capability validated on full range of parts over long periods
							Pilot system demonstrated	System incorporated in commercial design	Proven system ready for full deployment
				Component and/or system validation in laboratory environment	Laboratory scale, similar system validation in relevant environment	Engineering/ pilot scale, similar (prototypical) system validation in relevant environment	Full-scale, similar (prototypical) system demonstrated in relevant environment	Actual system completed and qualified through test and demonstration	Actual system operated over the full range of expected mission conditions
Software	Basic idea	Concept developed	Software to test and evaluate basic concepts on simple model problems representative of final need	Evaluate model to more realistic representation of industrial system. Confirm basic formulation	Model contains all major elements of need. Solve industrial problems by code developers OR achieve functionality by expert users. Document performance, GUI	No specialist intervention required from programmers/ developers. This includes basic GUI. If required, programming to be per ISO standards.	Install, run, and evaluate software in actual goal environment (e.g. client's computers). Demonstrate use by clients	Evaluation done by target representative hardware platforms. Complete GUIs, user manuals, training, software support, etc. Typical user-driven "bug hunting"	Product proven ready through successful operations in operating environment
Phase	**Research**			**Translation/Development**				**Commercialization**	

TRL Examples

The following examples are provided to give industry members a better understanding of how to assess the readiness level of an innovative technology. The first example follows the development of a single hypothetical technology, starting with the basic idea (TRL 1) and ending with industry approval (TRL 8) and wide distribution (TRL 9).

Example 1—TRL levels for a hypothetical sensor technology

TRL 1: Basic Idea—A university researcher proposes a sensor for detecting concrete slump based on the sound made by an object dropped on a sample.

TRL 2: Concept Developed—Using multiple samples, a student finds a correlation between slump and sound spectrograms generated by a steel ball bearing dropped from a consistent height above a fresh concrete cylinder.

TRL 3 and 4: Experimental Proof of Concept or Lab Demonstration—The student collects more data using the same setup, and then uses transfer learning applied to an existing convolutional neural network model to predict the slump of 30 unique concrete mixtures.

TRL 5 and 6: Lab Scale or Prototype Demonstration—A jig is created to ensure consistent drop heights, the app and jigs are provided to local testing agencies, and the data are used to test and further verify the algorithm.

TRL 7: Capability Validated at Pilot Scale—The app and jigs are provided to geographically diverse testing agencies that have agreed to collect field data using mixtures with widely varying properties. The data are used to further train and verify the algorithm.

TRL 8: Capability Validated and Incorporated in Commercial Design—The developers of the sensor system have published papers on their test method, worked with associations and approval agencies to develop a test standard, and developed a distribution network to sell the app and jig.

TRL 9: Capability Validated over Long Periods—The sensor is adopted as a rapid slump (and slump flow) test around the world.

The second example describes the early stages for a hypothetical binder system, starting with the basic idea (TRL 1) through laboratory or prototype demonstration (TRL 5 and 6). To provide a better understanding of the last three levels, existing technologies are described. LC3 is currently at about TRL 7, limestone cement is currently at TRL 8, and portland cement has been at TRL 9 for many decades.

Example 2—TRL levels for hypothetical and actual binders

TRL 1: Basic Idea—A university professor proposes the development of a net-zero binder for concrete construction.

TRL 2: Concept Developed—A research team uses chemical solutions to produce a binder from calcium-bearing minerals, and they verify that pastes produced using the binder and water develop strength comparable to portland cement pastes.

TRL 3 and 4: Experimental Proof of Concept or Lab Demonstration—A research team produces small amounts of a new binder from calcium-bearing minerals, uses the binder to produce small batches of mortar, and evaluates the working time and strength of the mortar specimens.

TRL 5 and 6: Lab Scale or Prototype Demonstration—A research team and partners produce a new binder in sufficient quantities to produce concrete pavers that are tested for compressive strength, flexural capacity, and durability when subjected to deicers and cycles of freezing and thawing.

TRL 7: Capability Validated at Pilot Scale—A cement producer modifies an idle kiln and manufactures enough limestone calcined clay cement (LC3) to produce demonstration pavements and structures and conduct workability, strength, and durability tests.

TRL 8: Capability Validated and Incorporated in Commercial Design—Multiple cement producers produce and sell limestone cement after more than a decade of durability testing and homologation.

TRL 9: Capability Validated over Long Periods—The world has been using portland cement to support civilization for hundreds of years.