Preparing the next generation of concrete construction professionals: the Concrete Industry Management degree

Vedaraman Sriraman & Jiong Hu

Texas State University-San Marcos
San Marcos, Texas, United States of America

ABSTRACT: The growing demands of the progressively changing concrete industry of the 21st Century prompted the development of a new construction-orientated academic programme called Concrete Industry Management (CIM). This industry-patented academic degree programme represents a unique academia-industry partnership. The first programme, established at Middle Tennessee State University (MTSU), was a very successful venture. In the past 16 years, four more such programmes were established in the United States. Examined in this article is the need for a new construction-related degree; what to teach; and how to teach in the context of a CIM programme. Also chronicled in this article are some challenges and opportunities that were realised at Texas State University-San Marcos, as a consequence of establishing a new CIM programme.

INTRODUCTION

As a construction material, concrete enjoys a prominent position. First, concrete is the most widely used man-made product in the world and is second only to water as the world's most widely utilised substance. Slightly more than a ton (0.91 tonne) of concrete is produced every year for each human on the planet - over six billion tons a year - and America uses even more, in excess of 25 tons (about 23 tonnes) annually per American. The use of concrete as an affordable, reliable material in the nation's construction, industrial, transportation, defence, utility and residential sectors is so pervasive that it is taken for granted [1].

The concrete industry is also the largest manufacturing sector in the United States. Within the industry, thousands of companies manufacture cement, ready mixed concrete, concrete pipe, concrete masonry, precast and pre-stressed concrete products [1]. This nationwide $US200 billion industry employs more than 500,000 people in a variety of careers [2]. Also, concrete materials and products are the foundation of the $931 billion construction industry, which is one of the major drivers of the U.S. economy [3]. In the US, the major states in this nationwide industry include Florida, California, Texas, Georgia, Arizona, Illinois, Michigan, Ohio and Pennsylvania. Among these states, California and Texas are dominant [1] The state of Texas is second nationwide in terms of volume of ready mixed concrete production and the number of plants.

In spite of the downtrend in the national economy, a closely related industry, construction, is the only goods-producing sector of the U.S. economy that is expected to grow through 2012. In fact, the U.S. Bureau of Labor Statistics (BLS) predicts that in the period 2002-2012, 1,096,000 more jobs will be created [4]. Additionally, some 1.4 million are expected to leave the industry owing to retirement and other jobs. Thus, net replacement needs will be close to 2.5 million positions. In Texas, according to the Texas Workforce Commission, during 2004–2014, the projected employment in construction industries is 660,350, representing a 22% change [5]. Generally, where there is construction, there is concrete. When concrete is required, there is also a need for professionals trained in concrete technology and business practices.

However, while there is a great demand for the professionals described earlier, the supply of such professionals is not very encouraging. The industry is anticipating a significant number of retirements in the near future. Graduates from related disciplines, such as civil engineering or construction management, possess a subset of the knowledge and skills called for. However, a broader technical and managerial background is required. While this undesirable situation is valid for the entire US, it is acutely felt in the state of Texas in general, and central Texas in particular. Central Texas, which is home to Texas State University-San Marcos, is also home to a wide variety of concrete and cement industries that are truly representative of the entire concrete food chain. How these national and regional workforce concerns were addressed is described in this article.

WHAT IS CONCRETE INDUSTRY MANAGEMENT?

As mentioned earlier, there exists a demand in the concrete industry for professionals with a background in concrete technology, construction management and business skills. The growing demands of the progressively changing concrete industry of the 21st century prompted the development of a new academic programme called Concrete Industry Management (CIM). The objective of the CIM programme was to produce graduates grounded in the basics of concrete production techniques and their use in a multitude of construction applications [6].

Concrete Industry Management programmes are greatly supported by the concrete industry. In fact, CIM programmes feature a unique industry-academia partnership that includes industrial partnerships at the national and local levels. At the national level, a national steering committee (NSC) comprised of industry-leading organisations, helps to provide funding for each university that offers a CIM degree and oversight and direction for the overall CIM programme. Organisations that support and participate at the NSC level include: the American Concrete Institute (ACI) Foundation; the Precast/Prestressed Concrete Institute (PCI); the American Society of Concrete Contractors (ASCC); American Concrete Pipe Association (ACPA); National Concrete Masonry Association (NCMA); National Precast Concrete Association (NPCA); National Ready Mixed Concrete Association (NRMCA); Portland Cement Association (PCA) and Ready Mixed Concrete (RMC) Research and Education Foundation.

In addition to working closely with the schools, the NSC has a strong partnering arrangement with each school's local patron group. The local patron group is made up of concrete professionals in the region or state wherein a CIM school is located. The local patron groups provide opportunities to engage the local concrete industry in advancing and growing a CIM programme. For example, the patron group at Texas State University–San Marcos funds and facilitates travel for CIM majors to the World of Concrete convention. As a consequence of this outstanding local and national industry support, CIM programmes have grown in quality and quantity in the past 16 years. The first CIM programme was created in 1996 at Middle Tennessee State University. Since then, four additional programmes have been created at the following universities: California State University–Chico, Arizona State University, New Jersey Institute of Technology, and Texas State University-San Marcos.

At Texas State University-San Marcos, the CIM programme was proposed in 2008 and established in January 2009. Currently, 65 majors are enrolled in the programme. There are strong indications that this programme will continue to grow. Figure 1 below indicates the growth pattern for the CIM programme. The next section deals with the curriculum affiliated with this new academic programme.

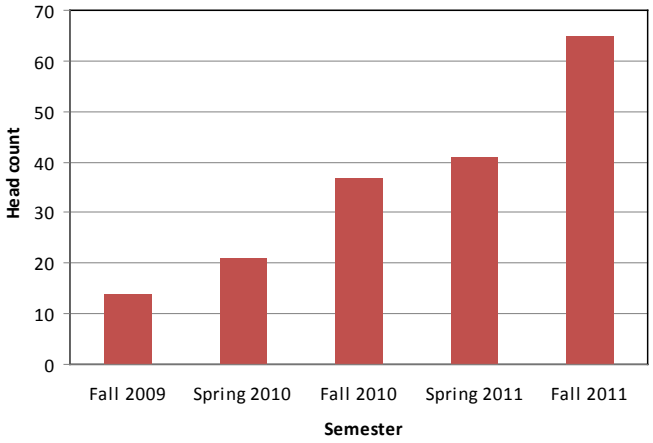

Figure 1: Texas State University-San Marcos CIM headcount.

WHAT TO TEACH?

The CIM curriculum has been influenced strongly by the following: a) the programme's conceptual base in concrete technology, construction management and business practices; and b) by the outstanding industrial orientation of the programme. The following provides the specifics.

As concrete is a major construction material, concrete-related courses generally exist in civil engineering and construction management (CM) programme curricula. While there is a one hour per week for six semesters requirement related to Construction Methods and Materials in the American Council for Construction Education (ACCE) criteria for the accreditation of CM programmes [7], there is no requirement for materials or concrete-related courses in the Accreditation Board for Engineering and Technology (ABET) language for the accreditation of civil engineering programmes [8]. Typically, ACCE-accredited construction or construction management programmes usually have one course related to construction materials, with approximately one-quarter to one-third of the content assigned to

concrete-related topics, i.e. aggregate, cement and concrete. In addition to the construction materials course offered in an ABET-accredited programme (either in civil or construction), a Steel and Concrete Design or Reinforced Concrete Design class is commonly included in the curriculum. While outstanding *design content* is covered in these courses, they barely touch upon the behaviour of the concrete material itself. This generally means that no more than half of the potential content related to concrete is included in the entire curriculum.

Due to the limited time available within these courses given the expected coverage, most of the courses focus only on the raw materials and on the mechanical behaviour of concrete. Consequently, there is insufficient class time to cover other aspects of concrete, such as mix design, durability and troubleshooting, which are critical from an industry point of view. As a result, despite concrete being one of the most dominant construction materials in the world, there have been no educational programmes that included the multifaceted aspects of the industry, such as concrete ready mixed plants, cement production, aggregate production, concrete masonry, and precast and pre-stressed concrete. Consequently, CIM curricula have been designed to provide the graduate with a broad range of experiences that thoroughly examine sales, operations, technical services, projects, production and concrete construction management concepts.

In order to meet the needs of the industry, the CIM curriculum at Texas State University-San Marcos is very broad based and ranges from foundation courses to those associated with conventional professional practices in the concrete industry. The programme provides students with a solid foundation of knowledge in concrete materials, production and construction applications. While the four-year curriculum comprises an integrated package, the curriculum may be grouped for convenience into three sets of courses. The first set consists of foundation courses in which students learn the fundamentals of pure science, mathematics, engineering science and business administration. These classes provide students with the background for a deeper understanding of technical and industry problems, and ultimately provide a 'tool kit' for any analysis that may be required to solve complex business and technical problems.

The second set consists of technical courses that include the areas of architectural design and drafting, concrete properties, concrete construction methods, statics and strength of materials, and the troubleshooting of concrete problems. In this set of courses, students are provided with ample hands-on opportunities to become fully familiarised with real-world concrete problems. The third set of courses addresses the issue of a liberal education for graduates of technical and professional programmes and would include classes in social sciences, humanities and related non-technical areas. This last set has been made an integral part of the CIM major's formal education because of the importance of graduates' awareness of their social responsibilities and the impact that new technologies have on society.

The heart of the CIM curriculum is a nine-course CIM core. The nine core courses cover both technical content and management perspectives related to the concrete industry and include:

- Introduction to the Construction and Concrete Industry;
- Fundamentals of Concrete: Properties and Testing;
- Concrete Construction Methods;
- Understanding the Concrete Construction System;
- Application of Concrete in Construction;
- Concrete Problems;
- Management of Concrete Products;
- Senior Concrete Laboratory;
- Culminating or Capstone.

The CIM programme at Texas State University-San Marcos is also deeply rooted in the application of business practices. In addition to the CIM core courses, a pattern of course work in business administration topics, such as accounting, business law, economics, finance and management, and marketing are included in the CIM curriculum. The 18-hour course pattern leads to a minor in business administration through partnership with the McCoy College of Business Administration.

In order to integrate a graduate's theoretical and practical knowledge of the concrete industry, the CIM programme emphasises hands-on experiences through participation in a variety of laboratory activities. In addition to the basic concrete laboratory activities, such as aggregate tests, concrete mixing, fresh and hardened concrete testing; advanced procedures to include concrete tests on durability, non-destructive testing and special concretes are incorporated in the curriculum. In order to implement the laboratory activities, a 3,000-plus square foot (279-plus square metre) concrete laboratory was built to incorporate the special needs of the CIM curriculum. Faculty members from Texas State University-San Marcos University worked closely with industry advisors to tailor the laboratory to satisfy both teaching and research needs.

The concrete laboratory is composed of three major portions viz. concrete mixing and testing, cement and mortar testing, and research and development. This concrete laboratory is not only equipped with fundamental tools offering students a full set of common equipment used in the industry, but also includes high-end instrumentation that exposes

students to the leading-edge of the industry. The laboratory set-up not only provides students enough space to perform routine tasks, such as concrete mixing, but also has designated areas for high-end tests. Table 1 indicates the major equipment and instrumentation included in the concrete testing laboratory. With the variety of equipment, instructors in different courses, including Construction Materials and Processes, Fundamentals of Concrete: Properties and Testing, and Senior Concrete Laboratory are able to include many fundamental and/or advanced laboratory activities in their courses. Examples of typical laboratory activities undertaken in the several CIM courses in support of experiential learning are listed in Table 2.

Table 1: Major equipment and instrumentation.

Categories of Tests	Major Equipment
Cement and aggregate property measurement	Cement fineness, flow table, planetary paste/mortar mixer, Vicat apparatus, sieve shaker, micro-deval, aggregate specific gravity test set
Concrete mixing and processing	Concrete pan mixer, concrete drum mixer, vibrator, masonry saw, jaw crusher, core drill, bench oven, curing room, environmental chamber
Fresh concrete property measurement	Slump, air content, flow table, concrete rheometer, self-consolidation concrete test set, gyration compactor
Hardened concrete property measurement	Compressive machine, abrasion resistance, compressometer and extensometer, strain indicator
Non-destructive testing	Schmidt hammer, ultrasonic pulse velocity meter, rebar locator, half-cell corrosion potential, maturity meter, concrete conductivity tester
Durability-related equipment	Freeze-thaw apparatus, rapid chloride permeability, isothermal calorimeter, length comparator

Table 2: Examples of typical in-class laboratory activities.

Laboratory Activity	Related Equipment
Aggregate properties	Sieve shaker, aggregate specific gravity, micro-deval
Concrete mix design	Slump, air meter, concrete mixer, compressive machine
Hot and cold weather concreting	Curing room, environmental chamber, compressive machine, maternity meter
Material incompatibility	Slump, air meter, maturity meter, calorimeter, compressive machine, Vicat apparatus
Non-destructive testing	Compressive machine, ultrasonic pulse velocity meter, rebar locator, half-cell corrosion potential, Schmidt hammer, concrete conductivity tester

In addition, the ACI Level I Field and Laboratory Testing, Technician certification has been incorporated into the curriculum. Students will be required to pass these certification exams to complete the course requirements in laboratory intensive courses such as Fundamentals of Concrete and Senior Concrete Laboratory. The enforcement of this certification in the curriculum will be beneficial, not only from a theoretical standpoint but also from a practitioner standpoint. In addition, obtaining this certification will strengthen a student's experience, thereby enhancing their future employment opportunities. Owing to the fact that the laboratory is well equipped, the certification exams are conducted in house in the concrete testing laboratory by private parties in Austin, Texas, who are associated with the ACI Central Texas Chapter.

AUTHORS' APPROACH TO CIM

The authors' approach to teaching in the CIM programme was strongly influenced by the fact that CIM is a practice-orientated degree, with a strong industrial focus. Thus, there is a focus on producing *industry-prepared* students. The guiding principle has been to expose students to real world applications through experiential learning and involving the industry in multiple phases of the programme. Significant involvement of students with industry occurs in two key ways.

First, each course invites multiple guest speakers selected from a variety of concrete industries to lecture on specialised topics that are considered to be a particular company's forte. Second, each course includes field trips to factories and work sites. While both industrial guest speakers and field trips are not unique to the CIM programme, the number of industrial speakers and field trips undertaken is unique to the programme. Such exposure broadens the student's horizons in the world of concrete. The programme takes full advantage of its location in central Texas, where there are multiple cement, aggregate, concrete, precast and prestressed producers within 30 miles (48 km) of the campus.

Professional development is just as important as the academic process and so students are also encouraged to participate in a series of industry-related activities hosted under the CIM programme. These activities compel students to make contacts early and often with industry professionals in order to gain from their experience and knowledge. Student participation in industrial shows such as the World of Concrete, and the annual ACI, International Concrete Repair Institute (ICRI), ACPA, PCI and NRMCA conventions not only promote the CIM programme but, more importantly, offer students unique opportunities for a stronger interaction within the industry and facilitates their securing quality

internships and jobs. All of these activities provide learning opportunities for students by which to groom their professionalism in the industrial environment and to benefit them upon graduation as they pursue future goals.

As part of the effort in furthering the professional development of students, an ACI student chapter was formed shortly after the activation of the CIM programme at Texas State University-San Marcos. The student chapter is open to all Texas State University-San Marcos students interested in concrete. The major goals of the ACI student chapter are to create an effective link between students and the ACI, to generate an opportunity for learning and networking between students and members of the concrete industry in Texas, and to promote student leadership and participation in local and nationwide ACI events and student competitions.

In order to be professionally successful in the concrete industry, it is important for students to be knowledgeable in concrete technology and techniques, and capable of applying knowledge in the real world. An industry-bound graduate is expected to have not only a conceptual understanding of contemporary concrete technology and practices but also to be competent in problem solving, as well. These aspects of the new discipline are addressed in the curriculum through the avenues of field experiences and integrative technical projects.

Such experiences present opportunities for solving practical problems in the concrete and cement industry under the supervision of practising technologists and engineers. In this regard, a Senior Concrete Laboratory course and capstone course are required for the CIM programme. The Senior Concrete Laboratory course provides students with an opportunity to further develop their technical and laboratory knowledge and pursue projects of individual interest. The primary goal of this course is to offer students industrial research and experimentation as learning experiences.

As one of the final courses in the curriculum, students are required to complete a three semester-hour senior design capstone class, which provides the opportunity to combine the knowledge from prior courses toward the solution of actual industrial problems. The capstone class is an intensive study of problems appropriate to the student's career interests and requires knowledge from previous technical and business course work. The primary goal of this course is to provide students with an opportunity to solve real-world concrete problems supplied by the industry. As the end result of this course, solutions to the problems will be presented to an industry committee. Students will be required to give a presentation demonstrating presentation skills, depth of analysis, completeness and effectiveness of the solutions.

Before graduation, students also will be required to complete three credits of industrial internship. This experience not only helps students gain credibility in the industry, it also enhances their knowledge, teamwork and interpersonal skills, and is preparation for a professional career. These internships will provide CIM majors with field experience that is difficult to gain in a university setting.

SYNERGY BETWEEN THE CONSTRUCTION SCIENCE AND MANAGEMENT (CSM) PROGRAMME AND THE CIM PROGRAMME

Texas State University-San Marcos also has a thriving CSM programme with close to 250 majors, six faculty members, and an active industrial advisory board. This section examines the synergies that exist between the two programmes.

The introduction of the CIM programme was of immense benefit to the CSM programme and vice versa. The first benefit is in regard to the curriculum. The nine new courses in CIM offer CSM majors a very rich set of new electives and immense flexibility in course scheduling, owing to the course substitution possibilities with CIM courses. The same advantage is realised by CIM majors in regard to the CSM courses. The concrete testing laboratory has also made it possible to increase the experiential learning aspects of some CSM courses, such as Construction Materials and Processes and Commercial Construction Building Systems.

The addition of three new faculty members to the department in support of the CIM programme has enhanced the existing faculty resources in the CSM programme. This is because all of the CIM faculty members have backgrounds very similar to CSM faculty members, i.e. all having academic and/or industrial experience in construction/civil engineering. However, they have added to the base of faculty expertise by virtue of their strengths in the area of construction materials. This, when coupled with current strengths of the CSM faculty in project management, scheduling, estimation and BIM (building information modelling), makes for a strong and well-rounded faculty.

An area where this advantage has made itself most manifest is in research, where collaborative efforts between the CIM and CSM faculty have yielded four Texas Department of Transportation (TxDOT) research contracts in the past three years. Lastly, the addition of the CIM programme has drawn new companies to the authors' bi-annual Construction Job Fairs. Consequently, there is now representation from an assortment of cement and concrete product manufacturers, as well. Lastly, the ACI student chapter associated with the CIM programme works closely with the Construction Student Association (CSA) in organising field trips, guest speakers and other activities. The healthy co-operation between these two student organisations helps to optimise resources. The exposure of students from either ACI or CSA to the other association is beneficial because the two disciplines (CIM and CSM) are not only similar but also directly related to each other.

CONCLUSIONS AND CHALLENGES

Outlined in this article is a new and unique academic programme with very strong links to industry and operating on the basis of an outstanding academia-industry partnership. The CIM programme at Texas State University-San Marcos has addressed the needs of the modern concrete industry in the state of Texas. This experiment is the first of its kind on this campus and has presented challenges encountered during programme implementation. Some of the challenges are shown below.

Civil engineering and construction management programmes enjoy considerable popularity in society, which in turn facilitates recruitment to these programmes. On the other hand, since CIM is a new academic programme with a rather short span of existence, recruitment of new students into this programme is challenging. Most of the current CIM majors at Texas State University–San Marcos are transfers from the College of Business or the Construction Management programme. In order to maintain a self-sustainable programme, additional efforts need to be made in the area of recruitment. Significant portions of these efforts necessarily will be to increase the awareness of students, parents, counsellors and the industry in regard to the CIM degree.

At Texas State University-San Marcos, concerted strides are being made towards it becoming a research institute, and so faculty members are expected to develop a strong research agenda that includes a productive publication track record and external funding. Most of the CIM faculty members at Texas State University-San Marcos have a traditional civil engineering background with an expertise in concrete materials or structures. They lack a business background and extensive real world experience, which can create challenges in teaching the industry-orientated CIM courses. In order to bridge this gap, the department is exploring the option of faculty internships to better prepare the faculty to teach these courses and by recruiting adjunct faculty members with considerable industrial expertise.

The authors' experience with this new programme, the challenges notwithstanding, has been very positive. First, as the previous section has detailed, many synergies exist between the CSM and CIM programmes. These synergies have resulted in a 'win-win' situation for the faculty, students and the broader construction industry.

Second, the new faculty and concrete testing laboratory have made innovative teaching and research resources available to the campus community. A recently funded project from TxDOT involved faculty members from the chemistry, biology and CIM programme. The availability of a well-equipped concrete testing laboratory was also a critical factor in securing funds. There are abundant opportunities for the faculty in engineering, physics, and materials science and engineering programmes, to collaborate with the CIM programme faculty.

Additionally, externally and internally funded projects offer CIM majors valuable experience as research assistants involved in real-life projects, as well as the use of state-of-the-art research facilities. Research topics related to concrete durability, sustainability, and innovative materials and technologies will be closely connected with CIM courses. Experience with front-end and multi-discipline research will help students to prepare effectively for future challenges in this dynamic industry.

REFERENCES

1. Roadmap 2030: The U.S. Concrete Industry Technology Roadmap. Concrete Research Education Foundation (CREF) (2002).
2. Concrete Industry Management: Degree Program to Careers in Concrete. National Steering Committee of Concrete Industry Management, Silver Spring, MD 20910 (2009).
3. The greening of concrete. California State University, Chico (CSU-Chico), *Sustainable News*, Winter 2009-2010 (2007).
4. Bureau of Labor Statistics (BLS) (2012), 12 January 2012, www.bls.gov/oco/
5. Texas Workforce Commission (TWC) (2012), 12 January 2012, http://www.twc.state.tx.us/
6. CIM: 2008-2009 Annual Report. National Steering Committee of Concrete Industry Management, Silver Spring, MD 20910 (2009).
7. Document 103, Standards and Criteria for Accreditation of Postsecondary Construction Education Degree Programs. Council for Construction Education (ACCE), American, San Antonio, Texas, United States (2009).
8. Criteria for Accrediting Engineering Programs (2010-2011 Accreditation Cycle). Accreditation Board for Engineering and Technology (ABET), Baltimore, Maryland (2009).