

# A CDIO CURRICULUM DEVELOPMENT FOR THE PROGRAM OF CIVIL ENGINEERING

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## **Abstract**

A design-directed curriculum based on CDIO principles was proposed for the program of Civil Engineering (for class of 2006 and later). The proposed curriculum utilizes design projects as vehicles to integrate all courses. The main differences of the new curriculum from the original one are reported. A fishbone diagram was developed for better showing the features of the new curriculum with an emphasis on the design projects. The design projects specifications are introduced as well. It is indicated that the designed-directed CDIO curriculum puts students in a broad and active design environment where they learn and use engineering science, technology and non-engineering knowledge; exercise their communication, project management, leadership and other skills. All projects are designs based on group projects in order to cultivate team spirit.

*Keywords: civil engineering, CDIO curriculum, design-directed, integrated project*

## **Introduction**

CDIO education curriculum [1] has been widely used in mechanical, aeronautical and electrical engineering programs. In order to realize the CDIO initiative better, a design-directed curriculum had been proposed and used in the College of Engineering, Shantou University [2]. The design-directed curriculum puts students in a design environment where they learn engineering science, technology and non-engineering knowledge, and when they need to use them. They are also required to work as a design team and exercise their communication, project management, leadership and other skills.

However, little material on using the CDIO initiative is available for civil engineering program. The challenge for civil engineering program is to design a design-directed curriculum based on the CDIO Syllabus and Standards [1, 3]. For example, CDIO Standard 5 requires that a curriculum includes two or more design-build experiences, including one at a basic level and one at an advanced level. However, civil engineering products, like buildings, bridges, etc, require long periods, large spaces, huge amount of money and special working skills to build. It is hence difficult to plan operating products to fulfill the design-build requirements (i.e. close to impossible to assume the same way as the other programs do in designing their CDIO curricula and the design-build projects).

Referring to the rationale of the standard, obtaining and iteration the design-build experiences are to “promote early success in engineering practice”, to “reinforce students' understanding of the product and system development process”, to “provide a solid foundation upon which to build deeper conceptual understanding of disciplinary skills” and also to give “students opportunities to make connections between the technical content they are learning and their

professional and career interests”. Great effort has then been paid by the authors to fulfill these objectives by overcoming the above difficulties for civil engineering program since 2005.

### Main Features of the Design-Directed Curriculum

Realizing the importance of the real world experiences and the difficulties to implement the students’ designs, an integrated approach, termed as design-directed curriculum for civil engineering program (for class of 2006 and later), was designed by the authors in order to achieve the overall objectives of the CDIO initiative. The main differences of the new curriculum from the original one are: (1) the new curriculum is “design-directed”, whereas the original one is “course-directed”; (2) the number of major design projects increases from 3 for the original curriculum to 6 for the new one, as shown in Table 1. Projects “Introduction to Civil Engineering Design”, “Engineering System Design” and “Integrated Design-Build Project” are not included in the original curriculum; (3) factors considered in the projects of the new curriculum are more than those of the original one. Environment, natural resources and professional ethics are included in the projects of the new curriculum.

In accordance with the requirement set out by CDIO Standard 5, in addition to the fundamental courses, an new course “Introduction to Engineering Design” (riding on a project) was designed for year one common engineering students [4]. This course provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills. The build-in design project of this course stimulates fresh students’ interest and creativity, exposes the students to the process of knowledge creation and development, and gives the students a sense of responsibility in social and historical contexts. This introductory course and its build-in project finished in semester 1 of year 1 are thought to provide a good starting point for students to perform their following design projects.

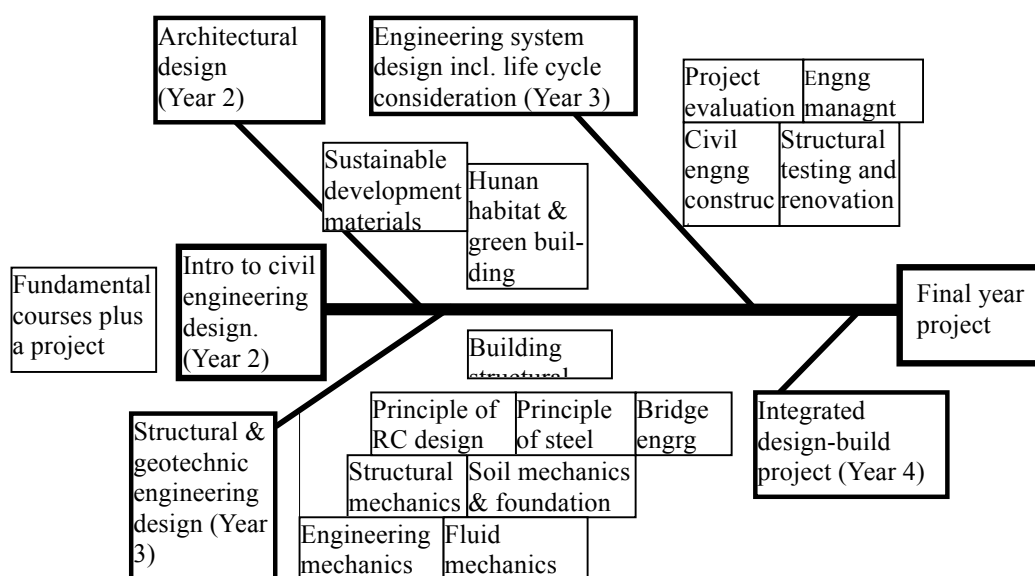


Figure 1. Main framework of the design-directed curriculum for civil engineering program

For year two to year four studies the new civil engineering curriculum can be illustrated by a fishbone diagram as shown in Figure 1. It can be seen that the proposed curriculum utilizes design projects as vehicles to integrate all courses. The trunk of the fishbone consists of a cornerstone project and a capstone project, both termed level 1 projects. The branches of the fishbone include four level 2 projects, each leads a cluster of core courses. Individual courses may also contain mini design-build projects, termed level 3 projects. All projects are design based group projects. The approach is hence termed as design-directed. The specifications of all level 1 and 2 projects are indicated in Table 1.

Table 1. Main projects in the new curriculum of the Civil Engineering program

Project	Stage	Project specifications
Introduction to Civil Engineering Design	Year 2 , Sem 1	Make civil plans for the new town. Pick up one item in the plan, such as a building or a bridge, to given more specifications on description/design.
Architectural Design	Year 2 , Sem 2	Refer back to their conceptual designs in the first cornerstone project, and modify original preliminary designs (such as buildings or bridges) with the new knowledge learnt in this cluster of courses.
Structural and Geotechnic Engineering Design	Year 3, Sem 2	Refer back to their conceptual designs in the cornerstone project and their “architectural design”, and modify their designs according to new knowledge learnt in the cluster of courses with a special attention on structural safety.
Engineering System Design	Year 3 , Sem 2	Refer back to their conceptual designs in the cornerstone project, their “architectural design” and “Structural & geotechnic engineering design”, and evaluate as well as modify their designs according to new knowledge learnt in the cluster of courses concerning the specifications and considerations of lifecycle design.
Integrated Design-Build Project	Year 4, Sem 1	To form multidisciplinary groups with students of other departments to search for possibilities of innovations either in civil engineering field or other professional fields.
Advanced Civil Engineering Design	Year 4, Sem 1 & 2	Work on a major construction development project, such as Shantou Metro system

### **Main Task of the First Level 1 Project**

As indicated in Figure 1 and Table 1, the cornerstone project (introduction to civil engineering design) will be carried out in fall term of year two. The students are given a stretch of land to plan a new town. With little knowledge on civil engineering, the students need to make civil plans for the new town. They will have to plan the residential, commercial, political, social, educational, and recreational districts and plan the traffic facilities, like roads and bridges. The purpose is to force the students to conceive civil problems with social, environmental and historical contexts. The key requirement for the students is “reasonability”. In order to prove the reasonability of the students’ designs, they will have to turn to various resources, which

work as a good introduction course and stimulate the students' interests. As the plans need only to be "reasonable" instead of being "correct or perfect", it has the effect to encourage creativity. In this project, each group also needs to pick up one item in the plan, such as a building or a bridge, to give more specifications on description/design. The students need to indicate the functions, format, styles, dimensions and materials to be used for the selected design.

### **Aims of the Four Level 2 Projects**

As shown in Figure 1 and Table 1, four level 2 projects were arranged and each integrates a number of core courses. Project "Architectural design" composes of human habitat and green buildings, and sustainable civil engineering materials. Project "Structural & geotechnic engineering design" leads courses in mechanics, structures and geotechnics. Project "Engineering system design" integrates courses in construction, structural assessment and maintenance as well as renovation, engineering management and project evaluations.

In the first level 2 project "Architectural design", students need to refer back to their conceptual designs in the cornerstone project, and modify their preliminary designs (such as buildings or bridges) according to new knowledge learnt in this cluster of courses with an emphasis on environment protection and resource saving. This project is different from the original one in the old curriculum, which doesn't consider resource and environment. The modified designs should be correct and good.

In the project of "Structural & geotechnic engineering design", students need also to refer back to their conceptual designs in the cornerstone project and their "architectural design". They need to modify their designs according to new knowledge learnt in the cluster of courses with a special attention on structural safety. Students are also required to make a balance between safety, aesthetics, feasibility, environment impact and energy consuming in their design. This balance was not included in the original project of the old curriculum. It is highly encouraged that each group of students modifies the designs finished by another group of students in cornerstone project and architectural project. Discussions, debates, understanding and compromising are expected in the communications.

In the totally new project "Engineering system design", students need to refer back to their conceptual designs in the cornerstone project, their "architectural design" and "Structural & geotechnic engineering design", and evaluate as well as modify their designs according to new knowledge learnt in the cluster of courses concerning the specifications and considerations of lifecycle design and macro-cost (including initial investment and anticipated maintenance fees) of engineering projects. Because this project provides students the opportunity to relate their design activities and decisions to social and professional responsibilities, this approach is quite different from the original one, which gives students all the engineering science and technology materials, but where most students have little or no engineering appreciation.

The last level 2 project "Integrated design-build project" requires the students to form multidisciplinary groups with students of other departments to search for possibilities of

innovations either in civil engineering field or other professional fields. It is expected that this project will lead to an intensive communication practice in students of the whole university.

After these projects, the students should have good experiences with “Conceiving”, “Designing” and partially “Operating”. The “Implementing” part will be made up by on-site internships. On construction sites the students participate in the implementation process of real world designs. However, whatever differences exist between the student’s design and the design of the real world construction, there must be some similar components/parts. The students are then required to pay special attention to those parts of implementation and hand in special reports on them.

### **Aims of the Second Level 1 Project**

The second level 1 project “Advanced civil engineering design” (final year project), works as the capstone to integrate what the students have learnt in their four years of study. These projects are large and complex, such as Shantou Metro system. The aim of this project is to reach the CDIO standards of “CDIO in an engineering and society system”. The key requirement for each student of a group is, as one member of a team, to provide a correct and feasible individual detailed design with technical and non-technical skills, and global insight such as social, environmental and historical contexts initiatively.

### **Content of the Level 3 Projects**

Design-build projects, termed level 3 projects, are placed in individual courses. Though the major purposes of these projects are to enhance the learning of the core courses, they also compensate the “implementing” deficits of the level 1 and level 2 projects. Examples of level 3 projects include the “Construction material design competition” and “Structural competition”. The former is actually a R&D project, which may yield practical solutions. The students need to learn the fundamentals of construction materials. They will then work in groups to make mix designs of Portland cement concrete for specific purposes, such as pavement or marine concrete. They will make the specimens according to the mix, test the specimens to validate the design. After that they will present their work to the class, discuss and defend their ideas. Properties, environmental impacts and energy consuming of the materials design and production by the students are all the evaluation indexes of the competition. The Structural competition links the theoretical analyses learnt from the course of “structural mechanics” to the physical world. Students of classes 2003 and 2004 have shown great enthusiasm for these projects.

### **Summary**

A design-directed curriculum based on the CDIO initiative was proposed for the program of Civil Engineering. The design-directed CDIO curriculum puts students in a broad and active design environment where they learn and use technical and non-technical skills, exercise and design. It is believed that this new curriculum complies with the CDIO initiative and standards. Evaluations and modifications will be continuously performed based on the practice of the new curriculum for the students of class 2006 and later.

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### **References**

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