Design and Realization of CDIO Elements in Civil Engineering Material Course

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Abstract: In order to cultivate creative civil engineering graduates with CDIO (Conceive-Design-Implement-Operate) competencies, a core engineering fundamental course, "Civil Engineering Materials", was redesigned and implemented since 2006. One of the main objectives of the course was changed into developing CDIO competencies through a teamwork redesign project. The curriculum synopsis, contents, teaching methods and the resource of course-books were re-designed to follow CDIO initiatives. The results of the teamwork redesign project and the students' assessment were discussed in this paper. It can be seen, comparing to reform before which performed by mainly using sitting, listening and testing fashion, that the ability, knowledge and personality of the students were effectively enhanced through such course reform.

Keywords: CDIO competencies, Civil Engineering Materials, Team design project, Teaching methods

INTRODUCTION

"Civil Engineering Materials" (CEM) is a core engineering fundamental course. The objectives of the course before reform was to enable students to understand, choose, mix and apply various materials correctly according to curriculum synopsis of china[1]. The main teaching and learning method were carried out by classroom teachings for 38 hours, and then demonstrated and validated experiments for 10 hours. The assessment was given based on a written examination and an experimental report at the end of the semester.

In 2006, Shantou University joined the CDIO Organization [2-3], and CEM was redesigned according to the competencies and standards of CDIO and implemented since then. The objectives of the course have been reform to: a) understand and apply materials correctly; b) understand and practice the process of designing and developing materials; and c) develop CDIO competencies through a teamwork redesign project. The curriculum synopsis, contents, teaching methods and the

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resource of course-books were re-designed to follow CDIO initiatives. The curriculum synopsis was set according to the "Ability Interrelated EIP-CDIO Mode" provided by the university. A web (http/www.matcv.stu.edu.cn/) was constructed to extend studying resources and to display students' projects.

CURRICULUM SYNOPSIS

The objectives of the course have been shifted from "enable students to understand, choose, mix and apply various materials correctly" to "develop new materials with a special attention on energy, resource, and environment problems" and to "cultivate CDIO competencies". In order to fulfill these objectives, the curriculum synopsis of CEM course was rebuilt with a reference to "I,T,U" method[4] as shown in Tab.1. Compared with reform before, the contents in CEM course were extended and increased as follow: 1.2 Production and application of civil engineering material considering social and resource problems; 1.3 Fundamentals on environmental friendly insulating materials; and 1.4 Teamwork redesign project with repeated C-D-I-O processes for developing a new material.

The levels of the related competencies to achieve after this reform are shown in Table 2. In order to discipline and cultivate the competencies of conceiving, designing, and implementing and operating systems in the enterprise and societal context, more attention was paid to 2.2 Experimentation and knowledge discovery, and 3.1Teamwork design project was also put forward and extremely emphasized as shown in Tab.2.

Table 1 Curriculum synopsis of CEM course after reform

	Detailed rules	Objectives			
		Knowledge	Comprehension	Application	Synthesis
TECHNICAL KNOWLEDGE AND REASONING	1.1 Basic civil engineering materials principles and knowledge	**B**	**B**	**B**	**B**
	1.2 Production and application of Civil Engineering Material considering social and resource problem.	**B**		**B**	**B**
	1.3 Fundamentals on environmental friendly insulating materials	**C**	**B**	**B**	**C**
	1.4 Teamwork design project	**B**	**C**	**A**	**A**

Table 2 Ability inter—related EIP-CDIO mode of CEM course after reform

		Instruction	Teaching	Utility
PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	2.1 ENGINEERING EASONING AND PROBLEM SOLVING		B	B
	2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY	A	B	A
	2.3 SYSTEM THINKING	B	B	C
	2.4 PERSONAL SKILLS AND ATTITUDES	C	B	B
	2.5 PROFESSIONAL SKILLS AND ATTITUDES		B	B
INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	3.1 TEAMWORK	B	A	B
	3.2 COMMUNICATIONS		A	B
	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES		C	
CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT	EXTERNAL AND SOCIETAL CONTEXT	D		
	ENTERPRISE AND BUSINESS CONTEXT	D		
	CONCEIVING AND ENGINEERING SYSTEMS		B	
	DESIGNING		B	A
	IMPLEMENTING		B	B
	OPERATING		C	

CONTENT AND METHOD

In order to reach at the objectives of “Ability Interrelated EIP-CDIO Mode” provided by the SHANTOU University and the curriculum synopsis as shown in Tab.1 and Tab.2, the contents of CEM course were redesigned; the significance differences of curriculum contents before and after reform were shown in Table 3.

From Table 3, it can be seen that the course contents after reform emphasize on self learning, teamwork spirits, system thinking, experimentation and knowledge discovery, and communication competencies. The course contents were composed of three parts. The first part containing basic civil engineering materials principles and knowledge was the same as reform before. This part was accomplished mainly through the classroom lecturing and self learning in 24 hours, a total duration of six weeks. The second part was an extension of what the students had to learnt and perceived, including the influence of material production and application on energy, resource, and environment.

Six hours in three weeks were allocated for the second part, and students needed to perform self learning, adopt system thinking and share through classroom discussions. The significance of this reform is the teamwork design project for developing new materials (such as a durable marine concrete, or an environmental friendly insulating concrete) in another 5 weeks. In order to fulfill the project's aim, students needed to perform self learning, adopt system thinking, engage experimentation and knowledge discovery and share through classroom discussions.

It also can be seen from Tab.3 that the assessment was also changed from "according to classroom examination and an experimental report at the end of the semester" to "the design report and the product display, as well as classroom examination." Then, the standard of grade was also changed. Before reform, writing examination and experimental report were made up 80% and 20% of the total grade respectively. And after reform, redesign process (including performance during design and final report) and writing examination were made up of 60% and 40% of the total grade respectively. The abilities of working independently and learning independently, as well as team spirit and communication skills were emphasized in this reform.

Table 3 Contents and methods of CEM course before reform and after reform

	Before reform	After reform
Contents	Master basic civil engineering materials principles and knowledge; Enable students to understand, choose, mix and apply various materials correctly;	Master basic civil engineering materials principles and knowledge; Enable students to understand, choose, mix and apply various materials correctly ; An extension of civil engineering materials principles and knowledge such as, production and application of civil engineering material considering social and resource problem; Knowledge about environmental friendly insulating materials; The teamwork redesigns project usual including repetitive discussion, design and practice process.
Assessment	1) Classroom examination 2) An experimental report at the end of the semester	1)Classroom examination, 2) Design report and display of products as well as routine performance

Grade standard	80% , writing examination 20% , experimental report	40% , writing examination 60%, t Design report and display of products as well as routine performance

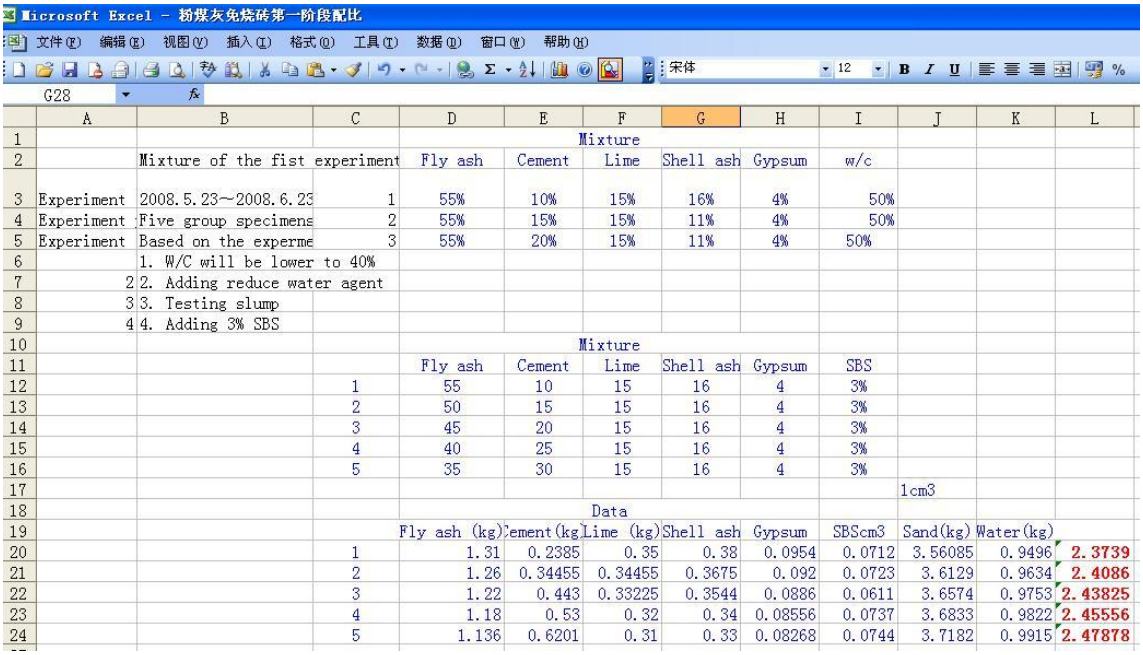
TEAMWORK REDESIGN AND CDIO PROCESS

CDIO competencies were cultivated mainly through completing a team redesign project in this course. The students were divided in groups, and each group was made up of four or five students. The title of the projects were provided by teachers or students themselves, such as 1) high-performance concrete used for high-speed highway; 2) high-performance concrete used for seacoast; 3) heat preservation mortar; 4) water resisting mortar and so on. Throughout the design process, teachers guided students to go through an entire CDIO cycle; the students' experienced independent inquiry learning, worked in collaboration with their teammates, and competed among teams.

The project was carried in two stages. The first stage was the design stage and the second was the evaluation stage. In the first stage, each team accomplished references reading and comprehending, mixture planning, raw materials selecting, sample preparation, testing procedures, results and discussion analyses, and received conclusions for the selected item. In the second stage, each team displayed their products, and whole class would then evaluate the design and give their comments on the design. The team displaying the design needed to defense or debate or accept the comments. After the evaluation, each team needed to revise its design according to the comments, and put forward another discussion, design and practice process.

Figure 1 shows a team completing a teamwork design project including discussion, design and practice process. The team tried to development a new wall material by using shell-lime and fly ash. The project was put forward after considering social and resource problem, and the new wall material would be an environmental friendly insulating material. First they accomplished reference reading and comprehending, then they selected raw materials and mixture planning based on the principles of environmental protection, energy-saving and materials on the spot. They applied the first mixture and found that the w/c ratio was high, leading to lower strengths, as shown in Fig.1a.

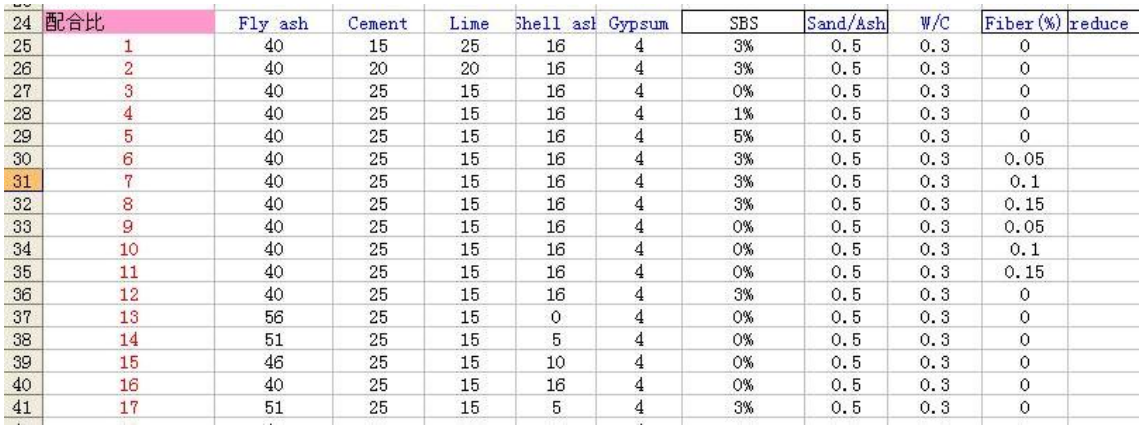
The team, then modified their mixture design according a further reference reading and discussion as well as suggestions of teachers and the students of other groups, as shown in Fig.1b. The polymer was added to enhance the tensile strength, the w/c ratio was reduced, and a new curing method was put forward in the second mix design. After the test and analysis for the second designed mixture as shown in Fig.1c, the third designed mixture was proposed by the students as shown in Fig.1d. It can be seen, that the students' innovative ideology, analysis ability, teamwork spirits, system thinking, experimentation and knowledge discovery as well as knowledge of CEM were effectively enhanced through such three times of CDIO process. The teamwork redesign project also improve students' ability to communicate with others and capability of self-learning.



Microsoft Excel - 粉煤灰免烧砖第一阶段配比

1						Mixture						
2		Mixture of the fist experiment		Fly ash	Cement	Lime	Shell ash	Gypsum	w/c			
3	Experiment	2008.5.23~2008.6.23	1	55%	10%	15%	16%	4%	50%			
4	Experiment	Five group specimens	2	55%	15%	15%	11%	4%	50%			
5	Experiment	Based on the experme	3	55%	20%	15%	11%	4%	50%			
6		1. W/C will be lower to 40%										
7	2	2. Adding reduce water agent										
8	3	3. Testing slump										
9	4	4. Adding 3% SBS										
10						Mixture						
11				Fly ash	Cement	Lime	Shell ash	Gypsum	SBS			
12			1	55	10	15	16	4	3%			
13			2	50	15	15	16	4	3%			
14			3	45	20	15	16	4	3%			
15			4	40	25	15	16	4	3%			
16			5	35	30	15	16	4	3%			
17										1cm3		
18						Data						
19				Fly ash (kg)	Cement(kg)	Lime (kg)	Shell ash	Gypsum	SBScm3	Sand(kg)	Water(kg)	
20			1	1.31	0.2385	0.35	0.38	0.0954	0.0712	3.56085	0.9496	2.3739
21			2	1.26	0.34455	0.34455	0.3675	0.092	0.0723	3.6129	0.9634	2.4086
22			3	1.22	0.443	0.33225	0.3544	0.0886	0.0611	3.6574	0.9753	2.43825
23			4	1.18	0.53	0.32	0.34	0.08556	0.0737	3.6833	0.9822	2.45556
24			5	1.136	0.6201	0.31	0.33	0.08268	0.0744	3.7182	0.9915	2.47878

a) The first mix design



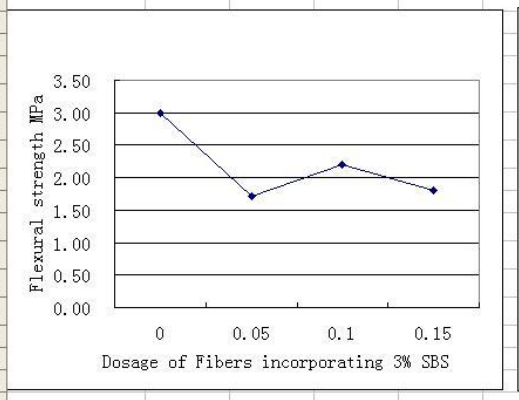
配合比	Fly ash	Cement	Lime	Shell ash	Gypsum	SBS	Sand/Ash	W/C	Fiber(%)	reduce
1	40	15	25	16	4	3%	0.5	0.3	0	
2	40	20	20	16	4	3%	0.5	0.3	0	
3	40	25	15	16	4	0%	0.5	0.3	0	
4	40	25	15	16	4	1%	0.5	0.3	0	
5	40	25	15	16	4	5%	0.5	0.3	0	
6	40	25	15	16	4	3%	0.5	0.3	0.05	
7	40	25	15	16	4	3%	0.5	0.3	0.1	
8	40	25	15	16	4	3%	0.5	0.3	0.15	
9	40	25	15	16	4	0%	0.5	0.3	0.05	
10	40	25	15	16	4	0%	0.5	0.3	0.1	
11	40	25	15	16	4	0%	0.5	0.3	0.15	
12	40	25	15	16	4	3%	0.5	0.3	0	
13	56	25	15	0	4	0%	0.5	0.3	0	
14	51	25	15	5	4	0%	0.5	0.3	0	
15	46	25	15	10	4	0%	0.5	0.3	0	
16	40	25	15	16	4	0%	0.5	0.3	0	
17	51	25	15	5	4	3%	0.5	0.3	0	

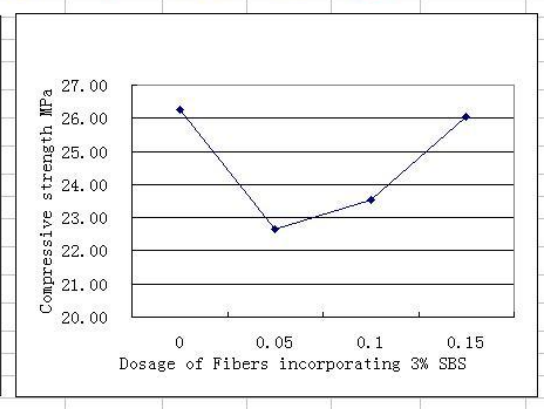
b) The second mix design

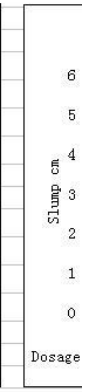
6	6	40	25	15	16	4	0.03	0.5	0.38	0.05	1.72
7	7	40	25	15	16	4	0.03	0.5	0.38	0.1	2.21
8	8	40	25	15	16	4	0.03	0.5	0.38	0.15	1.80

选用数据对比表

No	Fly ash	Cement	Lime	Shell ash	Gypsum	SBS	Sand/Ash	W/C	Fiber(%)	reduce agen	(MPa)
16	40	25	15	16	4	0	0.5	0.38	0		2.36
9	40	25	15	16	4	0	0.5	0.38	0.05		2.44
10	40	25	15	16	4	0	0.5	0.38	0.1		2.65
11	40	25	15	16	4	0	0.5	0.38	0.15		1.94







Data shows the incorporting fiber leads to both Flexural strength and Compressive strength decrease. It is incredible.

c) The result analyses

	A	B	C	D	E	F	G	H	I	J	K	L
1		Mixture of the third experment										
2		Fly ash	Cement	Lime	Shell ash	Gypsum	SBS	Sand/Ash	Water	Fiber(%)	educe agent (g	
3	1	560	210	350	224	56	16.8	700	420	0	7	
4	2	560	280	280	224	56	16.8	700	420	0	7	
5	3	560	350	210	224	56	0	700	420	0	7	
6	4	560	350	210	224	56	5.6	700	420	0	7	
7	5	560	350	210	224	56	28	700	420	0	7	
8	6	560	350	210	224	56	16.8	700	420	0.7	7	
9	7	560	350	210	224	56	16.8	700	420	1.4	7	
10	8	560	350	210	224	56	16.8	700	420	2.1	7	
11	9	560	350	210	224	56	0	700	420	0.7	7	
12	10	560	350	210	224	56	0	700	420	1.4	7	
13	11	560	350	210	224	56	0	700	420	2.1	7	
14	12	560	350	210	224	56	16.8	700	420	0	7	
15	13	784	350	210	0	56	16.8	700	420	0	7	
16	14	714	350	210	70	56	0	700	420	0	7	
17	15	644	350	210	140	56	0	700	420	0	7	
18	16	560	350	210	224	56	0	700	420	0	7	
19	17	714	350	210	70	56	16.8	700	420	0	7	
20	18	644	350	210	140	56	16.8	700	420	0	7	
21												
22												

d) The third mix design

Figure 1 Cases of enhance CDIO competencies by completing a teamwork redesign project

REFORM EFFECT ACCORDING TO RESPONDSES OF STUDENTS

Based on the faculty observations through the project process, the students' abilities and the students' learning efficiencies were significantly enhanced after this reform.

A student wrote in a personal reflection, "Through this project I further realize the virtue of EIP-CDIO approach. In the approach we learned how to study, how to communicate and how to cooperate. I have gotten a deeper appreciation of a civil engineer. I realize that we need not only to posses a rich, comprehensive professional knowledge, but also, more importantly, to be professional in learning and conduct".

Another student wrote in his personal reflection: "It is true that do more, learn more. We should pay more attention to practical abilities, such as independent thinking self-learning. Teamwork is not a work easy to be done; each member of a team must have his own unique insight in order to complete the project perfectly. How to communicate effectively, how to screen the useful knowledge, and how to use knowledge are all great challenges for us. It is true that practice is the sole criterion for testing truth."

One student reported: "The teamwork redesign project of CEM makes us really go into the construction practice. We resisted at first doing this project because we thought the experiment being hard, dirty and tired. However, during the project process we really felt the joy of the harvest of working hard, and understood the knowledge more deep-set through learning from practice. Here, I show my thanks to Teacher Li for providing us the good guidance, and I also thank my classmates for their good ideas to amend my project."

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