2nd International CDIO Conference
Linkoping University
Linkoping, Sweden
13 to 14 June 2006

THE 4th YEAR CIVIL ENGINEERING DESIGN PROJECT WITH CDIO ELEMENTS

Peng Lin, Yingzi Wang, and Guangjing Xiong

Department of Civil Engineering, Shantou University, Shantou City, P.R. China, 515063

ABSTRACT:

CDIO principles are being adopted in the Civil Engineering program at Shantou University, where student design teams are now involved in the 4th year design project. In carrying out the project, students were encouraged to develop and practice teamwork skills, practical engineering, and application of integrated disciplinary and non-technical knowledge, all of which are called for in the CDIO standards. The process and features of the project are presented to illustrate the adoption of CDIO elements. Problems, conclusions and suggestions are also discussed.

INTRODUCTION

In 2005, the College of Engineering at Shantou University adopted the CDIO education framework. The principles and standards of CDIO are being used to design and implement new curricula and course content in all the engineering programs. Most of the CDIO applications are in the areas of mechanical, aeronautical and electrical engineering programs. Therefore, most of the reference materials in CDIO were developed from those disciplines. Little material is available for civil engineering. The main challenge for the Civil Engineering program is the design and implementation of a curriculum based on the CDIO syllabus and standards. The proposed approach was the adoption of CDIO elements in a few selected courses, while redesigning the curriculum. One of the selected courses was the final year civil engineering design project.

Although 4th year projects in the Civil Engineering program are usually large and complex systems, such as metro or highway systems, students in the past were required to carry out the project individually rather than in teams. However, student design teams were used for this year's design project, the "Shantou-based metro system project", as an application of CDIO elements and standards. Two student teams were formed, each of which

consisted of four students. They were required to complete the project in fourteen weeks. One team of four students focused on the general plan of metro system and environmental design, including the scale control of the metro system, the selection of the metro lines, the arrangement of station location, and the architectural design of different themed stations. The other team of four students addressed the construction of the underground structures, including excavation of running tunnels, structure design and construction of metro stations.

In carrying out team-based projects, students are encouraged to develop and practice both technical knowledge and non-technical skills, such as teamwork and communication, which are called for in the CDIO standards. Because the students of the civil engineering graduating class have never had any courses with CDIO concepts, the adoption of CDIO in the new project was a challenge both for students and professors. The experience will be useful for developing and implementing the new civil engineering curriculum based on CDIO standards.

PROCESS OF THE "SHANTOU-BASED METRO SYSTEM PROJECT"

In the Shantou-based metro system project, eight students work together to complete it in fourteen weeks. The program of the project is outlined in Figure 1, which shows that the five parts of the work are systematic and interrelated, but also relatively independent.

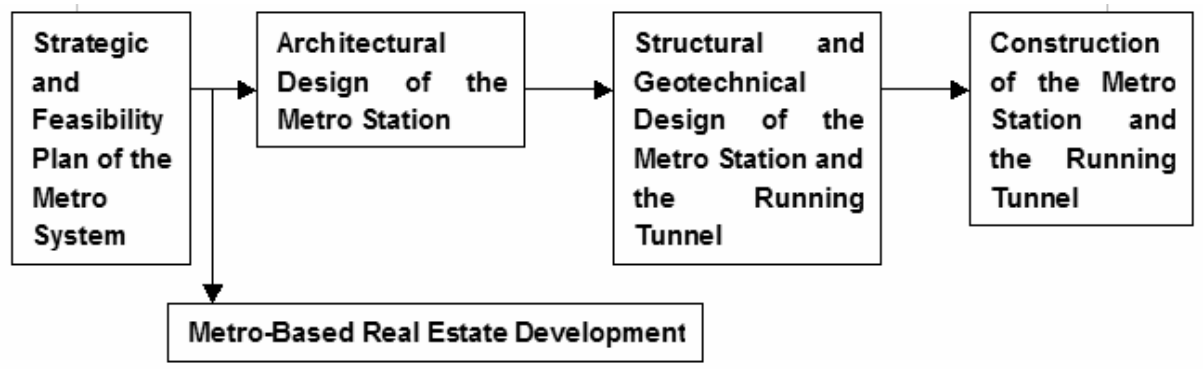

Figure 1: Program of the Metro System Project

In the general plan of the metro system, students do detailed analyses of Shantou City's population status, economic development and current traffic problems. The strategic and feasibility plan of the metro system would be the final outcome, as well as the selection of the metro line and the arrangement of the metro station location.

In the architectural design of metro stations, students consider the factors of environment, architectural function and esthetics, in order to give the architectural scheme for different themed stations. A series of dimension data of the building structure are also provided for further structural and geotechnical design. Figure 2 shows one of the architectural designs of a metro station.

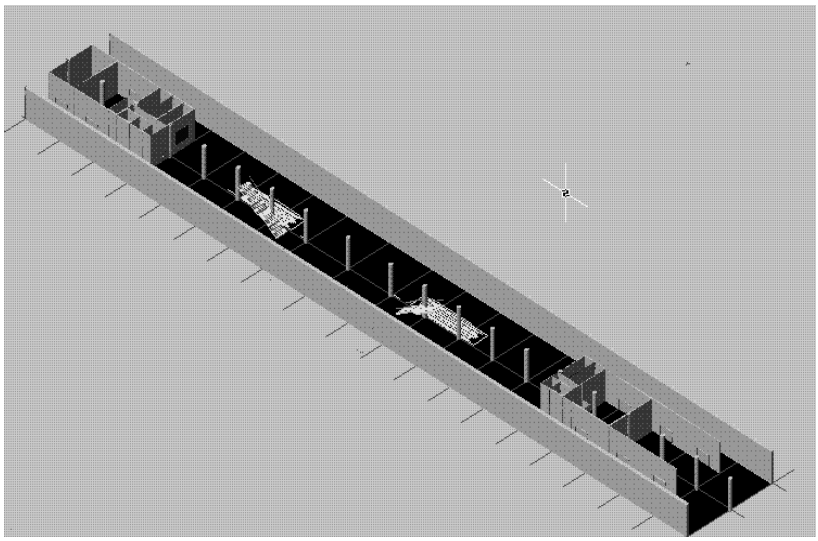

Figure 2: Architectural Design of the Metro Station

The real estate element is an interesting and attractive project. Students are given a block of land located beside the future metro station. According to the market analysis, they develop the land into a so-called house garden. They present a series of design schemes to support their sales and advertisement project, including the building arrangement, the department style and landscape design in the house district. Figure 3 shows part of a layout of the housing district.

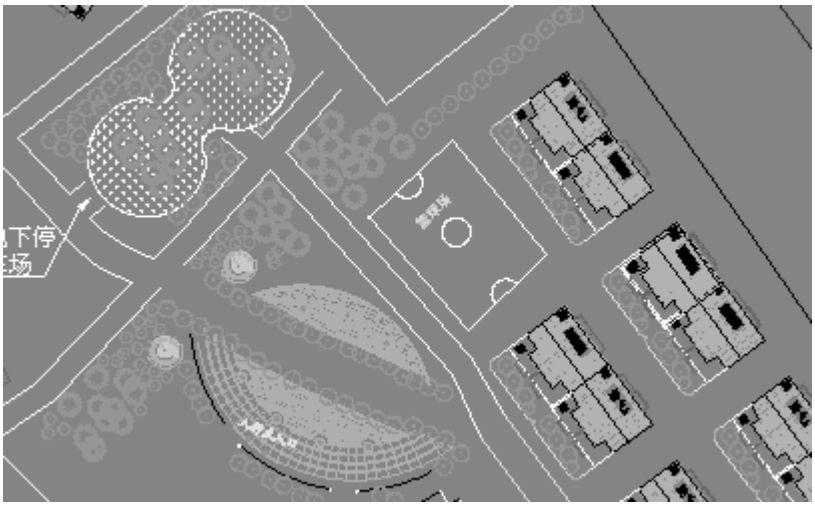

Figure 3: Part of Layout of the Housing District

According to the relevant architectural scheme, students carry out a series of detailed computations in the structural and geotechnical design. There is the underground structure of the metro station, the retaining structure of the excavation and the lining structure of the running tunnel, with numerous drawings to support them. Figure 4 shows the 3D finite element analysis of the metro station's retaining structure.

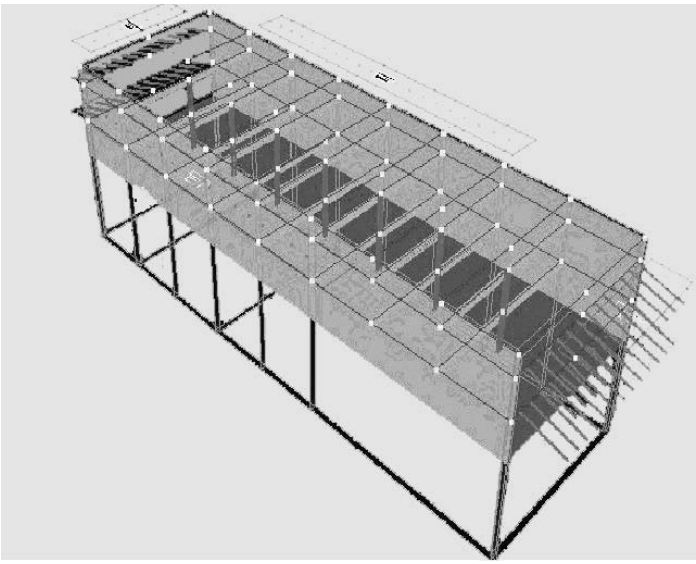

Figure 4: 3D FEM Analysis of the Retaining Structure of the Metro Station

The final part is the construction project of the metro station and the tunnel. The expected results are the construction setup scheme and the relevant bid contract.

As described above, in carrying out the project, students are required to know and engage in scheming, planning, designing and construction. The whole project is assigned to be as similar as possible to practical engineering, so that the team members are encouraged to simulate roles of the real civil engineering world, namely investor, architect, consultant and contractor. Interpretation of their roles includes conflict, interaction and compromise at different phases of the project. Students' skills of creation, teamwork, application of integrated knowledge and interpersonal dynamics will be significantly improved during the project.

TEAMWORK IN THE PROJECT

In the past, students were required to carry out the 4th year civil engineering project, which was usually large and complex, individually rather than in teams. This resulted in a lack of practical skills, like communication and interpersonal dynamics, in students. With CDIO principles being adopted in the Civil Engineering program, student design teams are,

therefore, used for this metro system project. In the project, team members are encouraged to work together and to have adequate communication and discussion to guarantee the fulfillment of the task. Although members are designated individual tasks, all members are involved in some important design schemes, such as the selection of the metro lines, the arrangement of the metro station location and the investment control of the metro system. In the members' individual projects, they are required to present their own schemes in meetings with all members meeting and to accept others' opinions and revise the scheme accordingly. Each part of the metro system is so relevant that it needs effective communication for further work. For example, dimension data of the structure attained in architectural scheme should be available for structural design. The construction process also relies mainly on the results of structural design, and vice versa.

After training in the project, team members should feel free to openly present their schemes and express their views. Teamwork should help them to complete such a large and complex project in only fourteen weeks.

SIMULATION OF PRACTICAL ENGINEERING IN THE PROJECT

The metro system project is assigned to be as close as possible to practical engineering, so that team members will be encouraged to simulate roles of the real engineering world, namely investor, architect, consultant and contractor. When discussing the whole project, they act as a team. But in their individual projects, they have their own positions and profit concerns. During the project, earning personal profit, coordinating with other team members and compromise, raises many problems in interpreting their roles. For example, students who are doing the strategic and feasibility plan of the metro system take on the roles of investors. They have the final influence in determining the selection of the metro station style, the construction method of the running tunnel, and so on. No matter how magnificent and attractive the architect's scheme, they will force the designer to choose the "moderate one" instead of the original splendid one, in order to reduce costs and remain within the budget.

Such conflict and compromise will often be seen during the project and also in the real engineering world. Team members' skills of presenting personal views, persuading the project partners and synthesizing various opinions will improve significantly. Through their efforts to be accepted by other members, they enhance their self-worth and confidence, which will be a great help to them when they enter the real engineering world.

APPLICATION OF INTEGRATED KNOWLEDGE IN THE PROJECT

Application of Disciplinary Knowledge in the Project

The metro system project provides team members with the opportunity to integrate their four years of knowledge in the discipline, as well as design and project skills. This, however, is not enough. Additional knowledge is inevitably needed to meet the demands of

the project; therefore, members are required to attain relevant knowledge by self-learning. For instance, in the geotechnical design of tunnel excavation, members have to search for additional knowledge through self-learning and the Internet to meet the demands of the project, such as shield methods in tunnel excavation and the special structure of three arch-span metro station, in addition to traditional curriculum knowledge like engineering geology, soil mechanics, ground improvement and excavation engineering.

In so doing, students extend their basic disciplinary knowledge to incorporate relevant project and design fields. This learning and working method will help them to become an effective engineer and will bring them lasting benefits.

Application of Non-technical Knowledge in the Project

In the project, we pay attention to increasing the students' economic knowledge and market consciousness, as well as developing their potential skills in product promotion. For example, in the metro-based real estate project, members are required to put forth a feasibility plan after enough market research. They present a series of design schemes in order to support their sales and advertisement project, including the building arrangement, style and landscape design in the district. The price and the building-up of the brand, in terms of the sales and advertisement scheme, is the expression of their potential economic skills.

In the construction project, students pay attention to the concept of cost and evaluate the engineering expenditure in order to give a bid contract according to practical engineering.

Although economic knowledge goes beyond students' disciplinary knowledge, they are introduced to the potential skill of costing, enhancing students' competence in the engineering world.

PROBLEMS IN THE PROJECT

Because team members had previously never had any courses with CDIO concepts, there were some problems during the project. There were difficulties in the application of non-technical knowledge. For example, when doing the strategic and feasibility plan of the metro system, students felt that it was difficult to tackle the economic data, like population status, market research, business networks, and so on. It took quite a bit of time to determine where to find this information and how to utilize it.

The other problem was that, at the beginning, students were not accustomed to team-based projects. They seldom gathered together to have discussions. The early discussions were also unsatisfactory due to the lack of system and routine; and, little help was provided in solving problems. Although those dialogues improved quite a lot as the project progressed, they had taken too much time and greatly impacted the project's schedule. It shows that it is important to have courses or projects with CDIO elements as early as possible in the Civil Engineering program.

CONCLUSION

As part of the CDIO implementation plan, the 4th year civil engineering design project, the metro system project, introduced some significant CDIO concepts and standards. In carrying out the project, students were encouraged to develop and practice teamwork skills, simulation of practical engineering, and application of integrated disciplinary and non-technical knowledge, all of which are called for in the CDIO standards. The result is that it was appropriate to adopt CDIO elements in the metro system project. It provided students with the opportunity to practice engineering problem solving and to improve their professional, personal and interpersonal skills. Future work should include the adjustment of the tasks' difficulty with students' ability and an invitation to practical engineers to be supervisors. To enhance students' non-disciplinary skills, it is strongly recommended that non-civil engineering students, such as students from the commercial college, be invited to join the project.

REFERENCES

[1] CDIO Initiative. "CDIO Initiative Homepage". www.cdio.org, 2005.

[2] Crawley, E. F. "The MIT CDIO Syllabus Report". Technical Report, The CDIO Inititative, www.cdio.org, 2002.

[3] Brian Surgenor, Chris Mechefske, Urs Wyss and John Pelow, "Capstone Design – Experience with Industry Based Projects", 1st Annual CDIO Conference, Queen's University, Kingston, Ontario, Canada, June 7-8, 2005.

[4] P. J. Armstrong, R. J. Kee, R. G. Kenny and G. Cunningham**, "**A CDIO APPROACH TO THE FINAL YEAR CAPSTONE PROJECT", 1st Annual CDIO Conference, Queen's University, Kingston, Ontario, Canada, June 7-8, 2005.

[5] Gareth D Padfield, "FLIGHT HANDLING QUALITIES — A Problem-Based-Learning Module for Final Year Aerospace Engineering Students", 1st Annual CDIO Conference, Queen's University, Kingston, Ontario, Canada, June 7-8, 2005.