The paradigm of Civil Engineering Education Within the Colombian Context

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Abstract — Colombia as a developing country needs to achieve a reliable, efficient and optimal civil infrastructure for facing the socio-economic challenges of this new century. The civil engineering profession has a significant role to play in this process and current civil engineering undergraduate programs are not training professionals in this direction. The pedagogic conceptions and teaching and learning methodologies are very traditional and do not provide the tools needed to ensure a sustainable development. There is evidence to prove that civil engineering programs should be modified substantially. The new Colombian civil engineer has to have not only basic and technical concepts of design systems, but also abilities to identify and solve complex problems, to communicate in an efficient way, to work as a part of multidisciplinary groups and to understand the responsibility and effect of his professional performance in society. This paper shows the needs required for a civil engineering program that responds to the Colombian context.

Index Terms — Civil engineering, Colombia, education.

INTRODUCTION
Statistical data show that the level of poverty in most South American countries is growing fast and the economic development is seriously delayed [1]. Within that context, there is a need for building a new and optimal infrastructure. Some examples of the required infrastructure are: water supply and sewage systems, housing and transportation. Therefore, it is clear that civil engineering has a very important role to play in the development of a country. Civil engineers should be outstanding professionals, able to face the challenges imposed by both the global trends and the local conditions. They have to have the skills for identifying complex problems, which usually involve other engineering fields, and solving them in an efficient and effective way by using the resources available.

Colombia is not excluded from this situation; the two main difficulties related to the civil engineering profession in Colombia are:
- The number of freshman students has decreased dramatically during the last decade (Figure 1).
- The civil engineering programs have important academic deficiencies.

In the first case, some universities have reported a reduction of 50% in the number of newly accepted students between two consecutive years. This situation is even more dramatic due to the fact that only 50-60% of the accepted students make the decision to register in the program. The situation is mainly caused by a severe economic crisis that has been going on in Colombia, as in other Latin-American countries, since the early 90’s. The unemployment rate has increased from 9% in 1994 to 18% in 2001, affecting mainly the construction industry. Since the employment possibilities for the civil engineering professionals are limited, most of the students who had ever considered studying civil engineering, are moving to other engineering programs. For instance, Figure 2 shows the distribution of the students in the Engineering School at the University of Los Andes (Bogotá, Colombia). It is clear that industrial and electronic engineering have gained great acceptance in recent years and that the share of civil engineering has decreased dramatically. However, the tendency varies depending upon the economic importance of the city and its socio-economic level. It has been observed that in intermediate cities and moderate to low socio-economic sectors, civil and mechanical engineering have greater acceptance.

Regarding the educational aspects, most academic programs were designed to respond to the country’s needs during the first part of the century. At the time, most universities did not have consolidated graduate programs and students were prepared to cover all those subjects during the undergraduate period. This policy led to over design programs and professionals who were more technicians than engineers. Nowadays, the main universities offer master and doctoral programs, which meet international standards. Nevertheless, in the last 50 years there has not been significant changes in the undergraduate programs; furthermore, the philosophies about knowledge, teaching and learning in the country are still out of date.
The current situation is giving Colombia the opportunity to re-think the way civil engineers are educated, specially, under the new global principles of teaching and learning methodologies. This means that the country has to identify the profile of the civil engineer it wants and adapt the new educational thinking to the local conditions. This paper explains the relation between the current Colombian context and the transformations needed in the civil engineering education.

THE COLOMBIAN CONTEXT

Colombia is located in the north-western corner of South America, with an area of 1,138,910 square meters and access to both the Pacific and the Atlantic oceans. It is a country with approximately forty million inhabitants, the majority of whom are Catholic and Spanish-speaking. Approximately eighty percent of the population is settled in the Central part of Colombia, the Andean Region, which is made of mountainous rugged terrain and exposed to many natural hazards (e.g. seismic, floods, landslides). Currently, some 75% of the population live in cities and about two million live as refugees in very basic conditions. The socio-economic distribution of the population is approximately 55% percent low, 35% percent medium and 10% high, with a distribution of 52% female and 48% male.

Some other important figures, related with the socio-economic situation of Colombia are:

- The unemployment level reached 18% in 2002.
- The current external debt is US$ 39 billion.
- 55% of the population lives under the poverty line.
- The GDP per capita in 2002 was US$ 6300 (PPP).
- The GDP current composition is 19% agriculture, 26% industry and 55% services.
- The most important natural resources are: petroleum, natural gas, coal, iron ore, nickel, gold, copper, emeralds and hydropower energy.

Unfortunately, despite its strategic location and the economic potential, Colombia has been ranked in the lowest places (54th) in the scale of world competitiveness [1] and is one of the countries least prone to foreign investment, not only due to the social conflict, but also to the poor and inefficient infrastructure.

In reference to its civil infrastructure, figures are also critical [3]-[5].

- The kilometres of paved roads per million of inhabitants is 2.5. This value is 90% smaller than in most European countries.
- The kilometres of railroads per million of inhabitants is 81.9. This value is about 7 to 10% of the railroad networks in the United States and Canada.
- The housing deficit is higher than the 20%. Out of the existing 80%, 14.8% of the urban housing presents overcrowding.
- Only 46% of the housing available have water supply, sewage and energy; and 20% does not count with any public services.

Studies show that there exists a direct relationship between the quantity and quality of civil infrastructure and economical and social development [6], [7]. For example, Figure 3 presents a relationship between the GDP per capita and the number of paved road kilometres for different countries. It is clear that, for developing countries, longer road networks, imply higher economic development. However, in countries with more than 6000 km of paved road per million inhabitants, extra-economic development depends of other factors (e.g., investments in high technology and services). Consequently, civil engineers in developing countries have a great responsibility.

Infrastructure needs in Colombia face severe obstacles. Long term planning is almost non-existent and infrastructure is commonly developed on the basis of the immediate needs, or under severe political pressures. There is not a consistent plan to integrate the country’s policy for competitiveness in the long term with the industrial needs and the investment in infrastructure. In addition, there is a very weak technical support to the design and construction of such infrastructure. Great part of the responsibility for these situation falls into the education system. The current low performance of the Colombian civil engineers, reported by the industry and the government, supports the proposal of changing the traditional education methods and programs.

THE CIVIL ENGINEERING EDUCATION IN THE COLOMBIAN CONTEXT

Civil engineering programs

In 1996, the Association of Colombian Schools of Engineering (ACOFI) and the Colombian Institution for Higher Education (ICFES) developed a project for studying the current situation of civil engineering programs [8]. The results were
discouraging. It showed that civil engineering programs are characterized for being rigid, linear and over designed. Furthermore, the programs do not respond to the future challenges of the country and do not offer the skills and attitudes required for the engineers of the XXI century [9]-[11]. The project recognizes the need to modernize and update these programs, including new methodologies of teaching and assessment. Nevertheless, since the end of that study there have not been important changes in the civil engineering programs.

Current civil engineering education in Colombia is basically the same as it was in the 50’s and 60’s. The curriculum modifications follow the same pattern in all universities: add, change or remove courses from the academic program. Table 1 presents the evolution of the civil engineering program at the university of Los Andes during the last 30 years [12]. Although a significant number of Colombian universities have adopted the credit system, the content of the courses and the pedagogic methodologies are still very traditional.

Comparing the 1975 and the 2003 program, it can be concluded that:

- In terms of credits, the 2003 program is four courses shorter than the 1975 program.
- There has not been important modifications in the civil engineering areas during the last three decades.
- The main changes are related to the inclusion of the construction management area and a few isolated courses such as pavements and road design.
- The number of compulsory courses in civil engineering are basically the same. There has been a reduction of two courses in the last 33 years.

In conclusion, the essence of the program has not changed. Even though the courses have now a higher component of technology, it is still very limited. On the other hand, teaching methodologies, with few exceptions, do not included an active participation of the student as the principle element in the education process. Table 2 presents the main characteristics of the civil engineering undergraduate programs in Colombia and Figure 4 an scheme of the current composition of the program in terms of the areas of knowledge.

Some of the weaknesses in the current civil engineering programs are:

- Programs are over designed. The number of courses is excessive for an undergraduate program.
- There is not a clear connexion among the different areas. The students attend the basic sciences courses but do not find a relationship with the areas that follow. By the time a student starts to attend advanced courses he realizes that he does not have the basis for assimilating the new knowledge.
- Courses have a high component of presence lectures. In some cases this implies more than eight class-hours per week. This overweight situation has two problems: a) do not encourage the students to do research; and b) limit the time the students need for individual or group activities.
- Most programs are rigid and linear. Students do not have room for being constructors of their own formation.
- The specific areas of knowledge have not been updated. While new technology is widely used, the programs are still tied to the classical civil engineering conception.
- Most programs do not contribute to the develop of skills and attitudes required in the engineers for the modern and future world conditions. (see ABET 2003 Criteria [13]).
- Most programs do not have the technological resources required by international standards. For instance, a typical civil engineering student does not have the possibility of interacting with specialized software and other technical resources.
- With the exception of some universitites, professors do not have a solid enough educational background.
- Research in all its levels is very limited and it is reduced to the particular interest of few professors.

Some of the most important universities in the country are working to overcome this problems. Furthermore, nowadays some of the programs they offer satisfy international educational standards and have been recognized by the ABET as similar in quality and content as North American undergraduate programs.

Comparison between Colombian and North American civil engineering programs

An exhaustive analysis of the differences between Colombian and North American civil engineering programs must differentiate among:

- The programs content and duration.
- The organization of the knowledge areas within the program and their relationship.
- The skills and attitudes developed in the students.
- The philosophical conceptions about knowledge, teaching and learning, which can be find in the program.
- The resources and tools that support the program.
A comparison between civil engineering in Colombia and in USA universities is presented in Table 3, [12], [14]-[17]. It can be observed that, in average, programs in Colombian universities contain twice as many courses than in USA.

In the American programs there is an almost inexistent separation among the six civil engineering areas. As a matter of fact, these programs include not only a great deal of elective courses, but also a new conception of civil engineering. For instance, traditional courses such as foundations and structural design, have been replaced by courses like graphic communication in engineering; civil engineering systems; engineering modelling under uncertainty; engineering design; planning, design and management of civil engineering systems; technical and scientific communication; and development systems.

Likewise, the skills and attitudes developed in the Colombian students are not enough for guaranteeing a successful professional performance. North American universities are very concerned in achieving the eleven outcomes required for the ABET Criteria [13]. In reference to these aspects, it seems clear that civil engineers in Colombia have weaknesses in: a) applying knowledge of mathematics, science and engineering, b) functioning in multi-disciplinary teams and c) communicating effectively.

The ways to develop those skills are closely related with the teaching and assessment techniques, and with the resources that support the programs. New pedagogical conceptions like active learning (constructivism philosophy), cooperative learning and peer learning have acquired great acceptance in the United States during the last two decades. Most of the programs recognize the importance of placing the student as the axis of the learning processes, which towards encouraging more active student participation (e.g. Problem Basic Learning, PBL, and Hands-on), and have moved away from traditional methodologies. The benefits of those conceptions have been proved by innumerable experiments conducted worldwide. For example, some authors [18]-[22] assert that team work allows the student to compare his world view with his classmates’, stimulating the consolidation of new knowledge. In this context the active participation of the students in their own personal growth seems to produce long-term benefits and could help to clarify the knowledge they have assimilated.

Although Colombian universities are moving slowly in these directions, some Engineering Schools are working on implementing active learning methodologies in the classroom. One example is the School of Engineering at the University of Los Andes, which is planning new curriculum based on active learning with physical modelling and lab-oriented activities. The strategy is supported by the new Engineering Education Research Group and the project to construct a new Engineering building (15,000 square meters) specially adapted for these new learning and teaching precepts.

THE CHALLENGE: ACHIEVE A NEW CONCEPTION OF CIVIL ENGINEERING EDUCATION

Colombia has today favourable conditions for changing the conception of civil engineering education. First of all, the government is taking action with regard to the quality standards of higher education and is willing to fund new educative proposals. Secondly, several ongoing research programs are looking at the possibility of re-design their current curriculum. These experiences are the foundation for the construction of new civil engineering programs consistent with its economic, social, technological and cultural realities.

However, for assuring an accurate and successful process there are some points that should be considered:

- Develop a national consciousness of the importance of the civil engineering profession and define the profile of the civil engineering the country needs.
- Promote the civil engineering programs among the senior high-school students, motivating them with a new conception of engineering education.
- Promote and prepare students with the abilities for facing the current and future challenges; this should included all sectors of society (e.g., academia, industrial and state organizations).
- Re-think the academic conception of the civil engineering programs. There should be balance among the courses (number and content), the relationship of the knowledge areas and the difficulties and necessities of the country.
- Recognize the existence of high quality graduated programs in the country and adjust the undergraduate programs in order to avoid over designed structures.
- Involve civil engineering students in real projects and show them the responsibility that the profession demands in Colombia.
- Promote the new pedagogical conceptions of active learning in the classroom. That implies to give the teachers the information, tools and support they need in the difficult task of changing traditional teaching methodologies. Particularly, it is important that the universities consider changing their traditional conception of laboratories as a practices of materials regulation to self-design experiments and modelling conducted by the students.
CONCLUSIONS

The civil engineering profession is paramount in a country like Colombia. The obsolete pedagogic system, which is not preparing the engineers with the skills for overcoming its underdevelopment and dealing with the economic challenges to come, has to be seriously reviewed.

The current civil engineering undergraduate programs in Colombia have important deficiencies. They are not only over designed but the current conception of pedagogical methodologies does not benefit the settlement of the long-term knowledge in the students. The country must think carefully which has to be the profile of the civil engineer that it requires. The civil engineer should have attitudes such as: competence, integrity, commitment, tolerance, flexibility and reliability. He/she should also have specialised skills in basic sciences, engineering applications, computer science and technology. Furthermore, the civil engineer should develop and consolidate communication, social, presentation, team-working, leadership and business management skills. It is difficult to assert that a program can give all these characteristics to a person, but it is possible to design a program which helps the person to achieve most of them by himself, during their professional development process.

The task of analysing, changing and designing new civil engineering programs is very complex, but should be conceived as a necessity of the country. It is time to face the challenge of transforming the traditional idea of engineers as a technicians to the idea of engineers as a integral professionals trained to face up the underdeveloped condition of the country.

REFERENCES

FIGURE 1
Percentage of variation of accepted students for three civil engineering undergraduate programs (private universities, Bogotá)

FIGURE 2
Distribution of student population. School of Engineering, University of Los Andes.

FIGURE 3
GDP per capita vs. road infrastructure development.
FIGURE 4
TYPICAL STRUCTURE OF CIVIL ENGINEERING UNDERGRADUATE PROGRAM.

TABLE 1
EVOLUTION OF THE CIVIL ENGINEERING UNDERGRADUATE PROGRAM, UNIVERSITY OF LOS ANDES.

<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Total credits*</td>
<td>170</td>
<td>170</td>
<td>164</td>
<td>158</td>
</tr>
<tr>
<td>Total courses (without laboratories)</td>
<td>57</td>
<td>57</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>Total of credits in elective courses</td>
<td>38</td>
<td>32</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>Number of specific civil engineering compulsory courses</td>
<td>22</td>
<td>25</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>New compulsory courses or areas</td>
<td>----</td>
<td>• Geometric design of roads</td>
<td>• Construction</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pavements</td>
<td>• Sanitary engineering</td>
<td></td>
</tr>
</tbody>
</table>

* A credit implies 45 hours of work, including presence classes and individual work. A normal course has 3 credits and a laboratory course has 1 credit.

TABLE 2
CHARACTERISTIC OF CIVIL ENGINEERING PROGRAMS IN COLOMBIA.

<table>
<thead>
<tr>
<th>Duration</th>
<th>5 years</th>
</tr>
</thead>
</table>
| Areas of knowledge | • Basic sciences (mathematics, physics, chemistry).  
                    | • Social/Cultural education*  
                    | • Basic engineering (courses common to all engineering programs)  
                    | • Basic civil engineering  
                    | • Advanced civil engineering  
                    | • Structures  
                    | • Water resources (fluids, hydraulics, hydrology, etc)  
                    | • Geotechnics (soils, foundations) |
| Areas in civil engineering | • Transportation  
                            | • Road infrastructure  
                            | • Materials  
                            | • Construction management. |

* Vary from one university to another.
<table>
<thead>
<tr>
<th></th>
<th>Los Andes (Colombia)</th>
<th>MIT</th>
<th>Berkeley</th>
<th>Illinois</th>
<th>GeorgiaTech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>5 years</td>
<td>4 years</td>
<td>4 years</td>
<td>4 years</td>
<td>4 years</td>
</tr>
<tr>
<td>Total courses*</td>
<td>51</td>
<td>37</td>
<td>25</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>Number of elective courses</td>
<td>12</td>
<td>9</td>
<td>8</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Number of compulsory civil engineering courses</td>
<td>22</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

* Without laboratories.