CHALLENGES OF THE EDUCATION IN CIVIL ENGINEERING

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Abstract. This paper presents a new strategy to organize the entrance examination at the Universities. It is based on the idea of free movement inside the university, following the interest and success of each student individually. It guarantees in addition that each discipline and department will get students with relevant basic education without any compromises. The strategy is very liberal and gives a student a possibility to choose his/her field by taking into account their own interest, but is then strict with all the requirements set for the education. It will also smooth all compulsory courses, which do not support directly the objective of major studies.

1. INTRODUCTION

Civil engineering has traditionally been rather theoretical and based strongly on Mathematics and Physics. Nowadays however, the basic education, starting already from high schools, has as compared to previous education, only restricted contents of Mathematics, yielding huge gaps in mathematical capability and in logical problem solving preparedness of new student generations.

As a teacher of Structural Mechanics, I meet continuously Master-students who do not know what trigonometric functions are, or how to differentiate them, or even worse I meet students who have still more fundamental lacks for example in calculating with numbers. It is extremely challenging to teach them successfully some more sophisticated theories of mechanics. I see that the role of mathematics is irreplaceable in the development process of a young student to use his/her own brain and thinking, in addition to give tools to solve various mathematical equations encountered, and also as a tool to develop individual's capability to logically formulate and solve various problems.

Civil engineering has not been the most popular subject between students when they are after the high school studies choosing their discipline for the future and entering Universities. Therefore, those ones who are not most talented nor interested in mathematical subjects, will often apply for engineering sciences, including both civil and mechanical engineering. The general opinion is believing that computers are taking care of all unattractive computation needed in the area. In the studies then, the weak fundamental knowledge of basics does not generate bigger interest in theoretical studies and the study years will increase. But because the Universities have defined at the same time their goal in shortening the years students will use for their studies, it is more or less forbidden to let them fail in examinations. This would catastrophically lengthen the study times. Finally, this path lead to the situation where the traditional knowledge of the graduates is alarming low. The results can be seen more and more

often in collapsing roofs and structures and numerous other problems and accidents in construction field.

Another problem inside civil engineering is due to the continuous need to extend the action field, covering many areas, which belong as a matter of fact to other disciplines as biosciences, chemistry etc. Consequently, the need for the contents of Bachelor studies on various areas of Civil Engineering is very different. However, at the Universities, the idea about common fundamental studies for all civil Engineering students is very strong, and therefore the contents adopted must be a compromise, which actually does not satisfy the needs of anybody.

2. HISTORY

The concept of Engineering has been originally devoted for Civil Engineering only, because no other engineering field was yet discovered. It covered all the activities on technical or theoretical technology for civil purposes - as opposed to the war technology. At Aalto University, Finland, even the student union was named as Engineering Guild, because no competing engineering area did exist. Much later, the concepts of Mechanical and Electrical Engineering guilds were launched and founded. Civil Engineering guild however saved the name Engineering Guild. In some countries, for example in Sweden, the concept of Civil Engineering covers all of the engineering areas, including Mechanical and Electrical Engineering.

Originally, the concept of engineering was connected to construction technology only. It covered erection of bridges, palaces, cathedrals, roads, water pipes and channels, etc. Civil engineering, in the way it is defined nowadays in Finland is a continuously and rapidly expanding area. It has never been a scientific discipline but serves as a field of applications for pure sciences, Mathematics, Physics, Chemistry, etc.

If we go backwards in the history, architects have been responsible of the design of structures, and also of building them up. They never needed any mathematical tool nor any calculations. Everything was based on experiences from previous generations and on the existing knowledge. When Galileo as a scientist started to study – actually as the Professor of Strength of Materials or Structural Mechanics – and developed various models to describe the behavior of structures under various loadings, the architects resisted strongly this kind of development by saying, that all the existing bridges, cathedrals and palaces were built up without any mathematical equation, and it is thus unnecessary to change the working practice.

Isaac Newton, who was a Mathematician realized in his time

> ‘*Structural Mechanics is the paradise of mathematical science because here we come to the fruits of mathematics’.*

Following Newton, the development in the design of structures was directed in increasing amount to mathematical applications and novel theories were invented continuously. Building up the American railways was a huge step forward in bridge engineering, and thus in Civil Engineering.

At the Universities, the development of the education in Civil Engineering was strongly based on Mathematics up to 1980's. Starting from the primary and secondary schools through the high schools, Mathematics and Calculus, including Algebra and Differential Geometry, were the corner stones of the whole education path in engineering field.

In the 1970's, when I started my studies at the University level, the basic education of Civil Engineering was composed of the same courses of Mathematics as the syllabus of students of Physics. Consequently, the whole study path was strongly mathematically oriented. These generations got a really strong theoretical education in Civil Engineering. The development has ended up in recent times to the situation, where the contents of Mathematics has gone down and covers only aboiut ten percent of that presumed 50 years ago. The high school education has gone down in Mathematics as well, giving a very weak basis for students to find the enthusiasm in this area. The problem has come immediately to Universities as well. This development can not be argued by the rapid development of numerical computation technique and effective computers. Vice a versa, understanding well the results obtained from numerical computations requires a many-sided fundamental comprehension about the correctness of the results and methods applied.

The syllabus of Civil Engineering education at the Universities is very problematic. As a discipline, Civil Engineering is not very popular. Young people who are interested in pure sciences direct their studies to Theoretical Physics, Mathematics and Chemistry. Those ones, who are more interested in Economics, will study Industrial Economics and Management etc. Among students, there is a competition on these most popular fields, and consequently, Civil Engineering is often the looser in this competition. The students coming finally to Civil Engineering are not the most talented ones nor interested in mathematical subjects.

The biggest problems concern those areas in Civil Engineering which are dependent in Mathematical analysis. Thus, the Structural Mechanics, where a strong basis in Mathematics is a necessity, is in problems. This is really not the first comment of this fact. It was noticed for example by Stephen Timoshenko who wrote already about hundred years ago:

> *'Later at universities in America, as a professor I encountered students who lacked proper mathematical training. I saw how this affected the level of teaching, which had to be lowered, adjusted downward to the students' level of preparation. Insufficient mathematical training has undoubtedly exerted great influence on the attitude of students toward the science of engineering. The American student, in most cases, is not interested in deducting any kind of formula, or in the basic assumptions underlying such deduction. All he wants is the final result – a formula which he can apply mechanically, without thought, to solve practical problems. It is my belief that the defectiveness of the mathematical education offered in American secondary schools during the early part*

of this century was one of the main reasons for the low level of development of the engineering sciences in the United States'.

Civil Engineering is a discipline, which is expanding rapidly. The original areas for the first Professorships were Bridge Engineering, Road Engineering, Water Resource Engineering and Geoengineering. To the recent times, new fields have been created, and will be created continuously. Biggest changes are concerning Building Technology with at first, separate professors and majors concerning all the building materials, concrete, steel and timber. Very important part has been Design of Structures, Structural Mechanics and Numerical Analysis. In addition, Majors in Building Economy, Management, Building Information Modeling (BIM) and Real Estates have been established. Still, Fire Safety Engineering, Building Physics, Building Services Technology, Heating Ventilation and Air Conditioning (HVAC) and Acoustics have own fields and professors. Newest areas in Civil Engineering are Inside Air Technology with links to Micro Biology, Clean Technology and Green Building Technology. The Geoengineering has expanded to the Geology, Geophysics and Rock Mechanics. In addition still, Transportation Engineering, Traffic Psychology and Environmental Techniques have widened the concept of Civil Engineering. A question will arise, in what way is the concept of Civil Engineering actually defined?

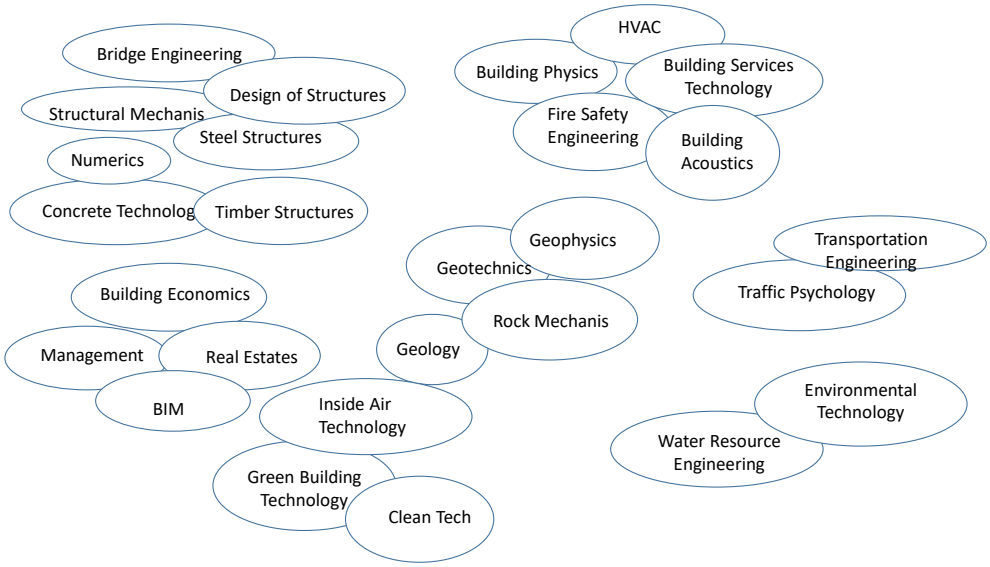

Fig 1: Map over Civil Engineering

It is not difficult to understand, that the need and requirements for the basic education in all these subfields is very different. Building up a common Syllabus for Bachelor studies in this way is impossible, or it will be a strong compromise, which does not satisfy anybody's needs. This is however the practice adopted in most Universities.

3. A NOVEL MODEL TO ORGANIZE BACHELOR STUDIES

When renewing the syllabus for Bachelor studies at Aalto University in 2011-2013, an alternative model was introduced. The most important pushing power or goal for this proposal was to move simply to the students themselves, the responsibility of their own studies. But at the same time, to give them the freedom to control and steer their own study paths up to the

Master level. One obvious goal for this proposal was also that every single major topic at the University will get in students provided with the necessary and relevant basic education – opposite to the strong compromise between all areas.

Practically this can be realized in the way where every single major subject at the University on Master level will choose those basic courses, which form necessary pre-requisites for studies, and allow successful continuation in this major. But it is fully free for a student to choose his/her major subject according to his/her own interest or success or any other reason. The size of Bachelor studies is all together 180 credits, of which we can assume that 60 credits will be taken by some general studies and Bachelor thesis. There are then 120 credits to be used for preparing professional studies. If we assume that each course consists of 10 credits, there are twelve courses covering the Bachelor education. Now, each major field can fix, say eight courses, which will be presumed to be passed before starting studies in this major. Four courses can thus be chosen freely by the student to support and complete the preparedness for the major he/she has chosen. Appropriately, this means that choosing the major a student has fixed eight courses for his/her Bachelor studies. This keeps the door open to the major chosen. By choosing the four additional courses, a student can open the door to some other majors. Doing this choice cleverly, he/she can prepare the entrance to the major alternatives, which are placed on the second and third place in his/her interest list. It will be very useful to do wise choices if for example the most interesting major is as popular that all interested students can not be accepted. Thus the qualification will take place according to the success in studies generally.

Later in the continuation of studies, a student can find out that he/she has done a wrong choice, and would like to choose some other major to replace the previous choice. Then, he/she can remove those courses from his/her program, which are no more conditional, and replace them with the courses to follow the requirements due to the new main major alternative. Those courses, which have been done already, will be utilized, and nothing will be loosed. This operation will close the door to the major area chosen at the first step, but open doors to some new major alternatives. And everything will be done according to the own interest of a student to be graduated in the field of his/her own interest. The contents of the study program will be changeable until the final term of Bachelor studies.

It will be emphasized that a student will have a possibility to choose the contents completely according to his/her own interest. The system takes care that the Master studies will always have relevant starting point with fixed prerequisites, and there is no need any more to talk about compulsory courses, which are not useful nor necessary in the studies on certain field.

At Aalto University, where three separate Universities have formed a merger allowing technology to meet art and economy in common surroundings, it is still possible to take a couple of additional steps. Each of these three fields have traditionally had own examinations for students to get into the University, and the requirements have been built up to support the goals of each field separately. The contents of the studies have however been assumed to be chosen mainly from the supply of each area separately. Now, it would be interesting to liberate still the praxis, by allowing all the students choose their studies on the supply of the whole University, independently of which type of examination they have attended to get into the University. This would fully release us from the limiting thoughts that only artistic people can have creativity, and vice a versa, as the situation is for example in the cooperation between architects and engineers. All the properties of young people could be utilized effectively.

4. CONCLUSIONS

The level of Universities and of excellence of graduates has been decreasing rapidly. Something really has to be done in the continuation to guarantee that we will still have excellent capable engineers on all the fields of Civil Engineering. The situation is at least very worrying when more and more complicated monumental buildings, bridges and other structures will be designed. It is a necessity that anyone can go without fear of the collapse into any building or walk underneath any bridge.

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