CAPACITY BUILDING IN COASTAL ENGINEERING WITH A FOCUS TO COUNTRIES IN TRANSITION

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Abstract
Coastal engineering is a complex art. At this moment a limited number of phenomena can understood with the help of the laws of physics and fluid mechanics. For the remainder, formulas have been developed with limited accuracy. In addition, input data are also limited available, and form another source of uncertainty. Consequently, a sound engineering approach is required, based on practical experience and supported by physical and mathematical models. Standard solutions do not exist in coastal engineering; solutions depend very much on local circumstances as well as the social and political approach towards the coast. Consequently the transfer of coastal engineering knowledge is a complex art as well. Because of the different circumstances, training of engineers from countries in transition therefore has to be different from training of engineers from a country with a strong coastal engineering tradition.

INTRODUCTION

Because of the rapid growth of the world population, mainly concentrated on the coastal zones, and because of a exponential growth in marine trade, there is a strong pressure on the coastal zone. This implies that the responsible authorities for these areas have to plan the future developments carefully, and start implementing regulations and prepare engineering works. Planning large scale engineering works is nowadays not very easy. It is not sufficient for an engineer to design a structure which fulfils the technical requirements, but it also has to fit into the environment. Engineering design is nowadays not an autonomous engineering process, there is a large input from the environmental requirements (nature conservation, pollution levels), as well as direct social requirements. This make that coastal engineering works (with usually a large impact on the environment) require a careful, and often lengthy planning process. Coastal engineers have to be trained in coping with these challenges.

An additional point for engineers is that the settings for coastal projects in the "old" world is different from the setting in emerging economies. And also in between countries in transition, there are large differences. For example, Bangladesh, China and Dubai are all in transition, but the setting for coastal engineers in these three countries is completely different. Consequently the required skills for engineers in these countries is also different.

ON-GOING CHANGES

Already ten years ago, a joined IAHR-UNESCO panel addressed the development in hydraulic engineering and their implications for the education of hydraulic engineers [KOBUS *ET AL.*, 1994]. Being specialized hydraulic engineers, many of the conclusions of this panel are also valid for Coastal Engineers. With reference to the UNCED '92, the panel concluded that "hydraulic engineering should be taught in a broad context of the natural and social environment and must enhance the *engineer's sense of responsibility* for sustainable water development within environmental and societal limitations."

TYPES OF ENGINEERS

Nearly 10 year ago, one could distinguish three types of engineers [VERHAGEN, 1996]:

- the research-engineers, involved in expanding the understanding of the coastal processes; using advanced analysis of field data and sophisticated physical models;

- the "toolmakers", engineers involved in translating the newly gained knowledge into mathematical models and encapsulate this knowledge in various knowledge based systems (Hydroinformatics, see ABBOTT [1994]);
- the design engineers (the tool-users), contributing in solving the coastal problems in a multi-disciplinary team.

The first two types of engineers produce products which can be used globally. Results from research done in Australia can easily be used in Iceland. Also (the better) tools can be used anywhere. Tools, developed in the Netherlands can easily be used in Sri Lanka. However, applying the tools for solving local problems requires the specific local knowledge of the various parameters of the system. In his keynote speech to Copedec IV, professor Hildebrando [HILDEBRANDO, 1995] gave an overview of the labour market for coastal engineers (based on Brazilian experiences), and he came to the conclusion that the demand for coastal engineers will grow in the following main fields of activities: Design, Construction, Operation and Research. He came also to the conclusion that the demand for researchers is relatively limited, compared to the other fields.

However, nowadays one may distinguish a fourth type of coastal engineer:

- the government official.

Although also in the past many coastal engineers were employed by governments, they usually could fit in one of the three types mentioned above. Government engineers in the past were mainly involved in making designs for governmental structures and supervise the construction.. So, usually they could be placed in the group "design engineers". However, nowadays there is a strong tendency within governments to contract out as much as possible. This implies that the number of design engineers within governments is decreasing. But governments still commission a lot of coastal works with engineering components, so within governments there is a need for engineers who are able to control design and supervision of works, but also are able to play an active role in the coastal planning process.

WHAT IS A COASTAL ENGINEER ?

An engineer is a trained person, able to solve practical problems in society (and in our case of course related to the coast), using technical means. In this paper I focus on the engineer with an academic education. From such an engineer it is expected that he is able to solve problems which cannot be solved by applying standard handbook solutions. Therefore he has to be able to understand the problem (analyze the cause of the problem), find in a creative way a path towards a solution of the problem, and implement that solution (make a "construction", however in this sense a "construction" is not necessarily concrete and steel, it may also be a beach nourishment or the implementation of a set-back system). Usually this process is called "design".

An important point is that the academically trained engineer has to bear "design responsibility". This means that he is responsible for the effect of the construction on the human and non-human environment. This includes of course the aimed effects (an erosion protection should protect against erosion), but also not non-aimed effects (an erosion protection should not increase downstream erosion without consultation with the downstream coastal manager).

So the main objective of the engineer is to <u>solve</u> the problem, only understanding is not sufficient. Understanding is only an intermediate step.

At this moment the process description in our profession is in many cases weaker than in other engineering professions. Many formulas used in coastal engineering are empirical or have important empirical coefficients (examples are the sediment transport formulas and the formulas for the stability of armour units). Apart from this, we usually have to work with considerably unreliable input data (e.g. wave data, waterlevels). And last but not least, the materials used in coastal engineering (rock) have a highly variable strength. The result of this all is that the main art of coastal engineering is the handling of uncertainties.

Because uncertainties are so important (and even will become more important in the future), a coastal engineer should have a good knowledge of statistics and probabilistic methods. In many engineering professions uncertainties can be handled by using a "safety-coefficient" or the use of a characteristic value (like the 95% value used in concrete engineering). However, because of the wide standard deviations in the distributions of the parameters common in coastal engineering, often only a full probabilistic approach leads towards acceptable solutions.

THE GOVERNMENTAL ENGINEER

In coastal engineering the "client" is often the government. Especially when considering coastal protection works (notably beach nourishments), the link between the paying organisation and the beneficiaries are sometimes unclear. This makes that financing coastal protection works is sometimes quite difficult and prone to an other form of uncertainties. As mentioned before, there is a tendency for governments try to contract out the engineering work as much as possible. It means also that the final designer is not part of the overall, initial planning team. Therefore it is important that within governmental teams there is engineering capacity. These teams should be able to know already in early stages the engineering pros and cons of several options.

TRAINING OF ENGINEERS

At most universities emphasis is put on the study of various coastal sciences for increasing our knowledge of the coastal processes. This is very important work, that has to be continued; however the consequence is that then students are only trained for this kind of research, and much less for practical engineering. So, in fact, we are mainly training the first 2 types of engineers, and neglecting the type 3 and 4 (the design engineer and the governmental engineer). Therefore it is necessary that apart from the education of coastal researchers attention is also paid to the education of engineers, i.e. people who are able to solve practical problems and design solutions.

When one analyzes "problem coasts", in most cases the coastal engineer is confronted with several types of problems. Among others, the following types can be distinguished:

- the "obvious" mistake;
- lack of data (no accurate boundary conditions);
- no accurate design method available.

The most usual problem is the "obvious" mistake. For example, buildings constructed too near to the waterline at an eroding coastline, undesirable effects of downstream erosion due to coastal works, etc. In these cases the origin of the problem is not really an engineering problem, but absence of awareness of coastal behaviour at (political) decision making level. It is more a political problem than a technical problem. A better technical training of engineers will never solve this kind of problems, one has to create coastal awareness at the group of clients. This requires communicative skills and the ability to compose clear and understandable reports. Usually this is a weak point of technical people, therefore special attention has to be paid to this point in the education of engineers. Especially for the increasing group of governmental engineers, this aspect is very important. Engineers working in a governmental environment have the task to prevent that planners and decision makers, trained in other professions, make this kind of "obvious" coastal engineering mistakes.

Often no detailed input data are available for making an appropriate design. Accurate long-term wave data are very scarce. This means for an engineer:

- he has to learn how to "generate" data (hindcasting, combining several sources of data, etc.)
- he has to learn to make the design in such a way that the influence of unreliable input data is as minimal as possible (for example using probabilistic methods).

In order to solve the third kind of problem (no design method available to the designer), he first has to find out, if such a design method exists somewhere in the world. This means that he should be trained in searching for this type of information. And finally in those cases where no design method is available, our engineer has to perform his own research (or write an research assignment to be executed by a specialized institute). In some cases this is necessary. But in 90 % (or more) of the design cases, this is not relevant.

Having made a (far from complete) overview of academic coastal education in the world, the conclusion is that in those universities where coastal engineering is presented, it is usually a specialisation of civil (or hydraulic) engineering, offering only a few graduate courses really in coastal engineering. The most common situation is that in the final year, the hydraulic engineer can follow a few lectures in specialised coastal engineering topics, followed by a thesis on the subject. Also there is a large group of universities offering coastal sciences as a part of a course in ocean sciences or earth sciences. Unfortunately in these courses hardly any attention is paid to the typical engineering aspects of the coast. They focus on the physical processes of the coast, and do not train students in solving problems in a human context.

For a practising engineer, working in a multi-disciplinary team, it is vital to know the physical processes instead of only knowing the mathematical approximation of these processes[1]. In education this point is often underexposed. Especially in the education of

[1] A clear example can be found in wave-mechanics. Often teaching starts with the dispersion equation for gravity surface waves (in fact a mathematical model description). And then, for example, refraction is explained by combining the dispersion equation with the continuity of wave crests in order to get a formula for the ray curvature. Usually this is not very clarifying for students with an engineering attitude.

engineers from developing[2] countries attention has to be paid to the education of the design (type 3) engineers, see VERHAGEN [1995].

NEEDS OF COUNTRIES IN TRANSITION

When looking to the needs of countries in transition, one sees that they have in common a scarcity of staff with engineering knowledge on all levels. This means that for the time being, a lot of work has to be contracted out. As long as sufficient money is available, it is no problem to hire good engineering capacity. However, still one has the problem that within the decision making bodies (the government) not sufficient engineering capabilities are available. This means that in fact the highest priority for countries in transition is to get engineering capacity within the governmental body, with the objective to guide the decision and planning processes in such a way that the final plans are sound from an engineering point of view. This is applicable for all types of countries in transition.

The second priority for countries is to manage their own assets. This means a need for engineers able to manage existing structures and to design simple adaptations of the infrastructure. In case of a shortage of people, this task can be carried out by hiring long term staff from overseas. It is not recommended to contract out this kind of work in short term contracts. For the management of coastal structures a continuity is needed; therefore this work should not be split over several different consultants. Of course for specific tasks, external consultants can be hired. The overall planning of these activities should be managed by a local agency. For countries in transition with sufficient financial support but shortage of (trained) people hiring foreign staff to work in their own agencies is a good option. For countries with a large population but limited financial resources, there is a very strong need to recruit this staff from their own population. But this means a extra effort in training.

An important difference between engineers working in a country in transition, and engineers working in countries with a longer Coastal Engineering tradition, is that in the second case a young engineer is always surrounded in some way by more experienced engineers. In countries in transition the young engineer is often surrounded by senior staff, not being coastal engineers.

BOUNDARY CONDITIONS FOR TRAINING

One could formulate the task of a coastal engineer as:

> *to make a reliable and economic design, based on rather unreliable input, computational results and taking into account the available resources.*

Post-graduate training should realize an upgrading of staff such that they can fulfill the above defined task.

In addition to the difference in the technical aspects of coastal engineering between the traditional CE countries and most of the countries in transition, other differences play an important role:

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[2] In this paper a "country in transition" is defined as a country with no CE-tradition and a strong development; a "developing country" is defined as a country in transition with insufficient own financial resources.

- *career development*. In countries with a CE-tradition, the young engineer gets a good basic education at university, where he learns all the fundamentals of coastal behaviour. In his first job, a young engineer learns how to apply this fundamental knowledge. As starting engineer, he will first be involved in projects guided by more senior coastal engineers, so that he can build up experience and get a feeling for the relativity of the computations. In other words, the young engineer can build up experience in a rather protected environment. Therefore, the education in industrialised countries should mainly focus on the basics of coastal engineering and on understanding of processes. For engineers from countries in transition this focus is not enough. In most cases, young engineers do not have the luxury of obtaining experience like indicated for those in countries with a CE tradition. After graduation, they almost immediately are put in a position as 'expert'. In addition, when they are guided by a more senior engineer, than often this senior engineer is not an experienced coastal engineer [VERHAGEN, 1996];
- *engineering network*. Keeping in touch with the profession is very essential, which requires an engineering network. In the 'non-traditional CE countries', however, a network of experienced coastal engineers is often absent. So, our young expert can not go to his former study-mates or to a specialised library for consultation. Fortunately, electronic data communication eases the life of the remote engineer nowadays. He can have access to computer libraries and make contact with colleagues on the other side of the globe;
- *engineering facilities*. Availability of well equipped laboratories, computer models, computers, measuring equipment, vessels, etc. is a pre-requisite for successful coastal engineering. However, developing countries often lack these facilities or face problem in obtaining finances for operation and maintenance of these facilities.

An additional factor is that CE knowledge and expertise at post-graduate level is only available in a few countries (to illustrate this: both at the ICCE'98 and at the ICCE'04 there were only 9 countries with more than 10 papers presented). The need for CE technology, however, is high in many countries all over the world, especially in countries in transition. Here, problems are increasing, both in complexity, number and magnitude, whereas the resources are very limited available.

CONSEQUENCES FOR A TRAINING PROGRAM

Transfer of CE technology at post-graduate level for countries in transition should aim at increasing the capabilities and skills of the design engineers such that they can analyse CE problems and identify possible directions of solutions themselves. A sustainable transfer of technology implies a decrease dependency on foreign expertise.

Essential elements in such transfer are:

- bringing engineers and experts together, so that they can exchange knowledge, views and experiences;
- introduce engineers to practical tools (such as software) and learn them when to use them and how to interpret results;

- expose the engineers through exercises, case studies and field visits to CE practice with the emphasis on the underling philosophies that have lead to certain solutions;
- expose the engineers to the decision making environment where multi-disciplinary teams (including coastal engineers) prepare the decision making process.

Availability of experts
Direct personal communication with a relatively large number of experts and exposures to CE examples in the field are essential elements of realizing sustainable transfer of CE technology.

Bringing engineers and experts together is a main problem: experts are mainly located in a few countries with a CE tradition, whereas the need for training is worldwide. Further, the experts are very limited available. So the engineer has to come to the experts. There are three possible solutions:

A. the engineer attends a *post-graduate coastal engineering course* at a university in a country with a CE-tradition. However, major difficulties of this option are:
   1. the number of post-gradual training courses is very limited and only given in traditional CE countries;
   2. post-graduate training programs are often PhD programs, which mainly focus on research. And this is not what our design engineer is looking for;
   3. the engineer has a completely different background and reference level compared with that of the fellow students and the lecturers;
   4. the course may be geared to the specific needs and circumstances of the country where the course is given;

   Consequently, the engineer runs the risk that he/she ends up with a course, that is just partly relevant for the specific needs of his/her own situation;

B. the engineer attends a *regular masters course*. Characteristics of this option are:
   5. the number of masters courses is limited and the majority is located in countries with a CE-tradition.
   6. in addition to the sketched difficulties A1 and A2, the fellow students come directly from the under-graduate program and consequently lack practical CE experience;

   A complicating factor of options A and B might be the language. The majority of these courses is given in the native language, which should be mastered by all students. When this is not the English language, our engineer first has to spend a lot of time (several months up to one year) and effort to learn this language before he can actually start the course.;

C. engineers from all over the world come together at a location close to the experts and attend a training course that is geared to their specific needs and backgrounds, and where they can share their experiences with colleague engineers. There are only very few of these courses available in the world (e.g. at Unesco-IHE in Delft).

A new option is an interactive, internet course. These distant learning courses are the successors of the old-fashioned correspondence courses. An example is the Coastal Engineering Certificate Program, from the Old Dominion University. The purpose of this course is described as*: to provide practicing engineers the opportunity to study Coastal Engineering at the graduate level to help them in the practice of their engineering profession. The Certificate demonstrates a basic level of understanding of the physical sciences, engineering, economics, the environment, institutional-political-social, and aesthetic constraints that influence all coastal engineering design.*[Old Dominion website, 2005]. But like it is clearly stated in this purpose, the program is intended for engineers who have already practical experience, but are in need of additional practical knowledge. Therefore such programs are more focused on knowledge transfer, than on attitude transfer. This makes that on-line courses are very useful for a number of students, but most probably not for inexperienced students from countries tin transition. Specific aspects can only be learned by students through working together in a group. This process is extremely difficult to carry out via the internet without working in the same location.

A clear benefit of on-line distant learning courses is that updating the existing knowledge of engineers can be organized in a much easier way. Therefore distance learning will play a very important role in the continuing education of coastal engineers.

Orientation of training

The training should be geared at understanding the underlying CE processes (copying solutions from the industrial countries usually do not lead to the most optimal/economic solution for their own problems), and the development of conceptual thinking (as to decrease dependency of foreign CE expertise). Background for such approach is:

- *ongoing developments in the CE field*. Training students in the use of formula only is not that relevant, because the current formulas will be replaced by newer and better ones. For example, nowadays one can better use the Queens formula instead of the CERC formula, or the Van der Meer formula instead of the Hudson formula. In other words, because of the ongoing research in our profession, formulas are continuously replaced by others. Therefore, after training our engineer should be able to:
    - know about these new developments;
    - judge the quality of these new formulas (are they better?? for which conditions are these formulas developed?? what are the limitations in use??);
    - learn himself how to use a new formula;
- *latest techniques*. For the complex CE problems and the limited data available, the coastal engineer from a country in transition has to have access to the latest knowledge and techniques. The training should be geared such that the student is able to use newly developed models;
- *capacity for interpretation of engineering results*. This refers to training students in the interpretation of results of a given a computational method. For example, if the outcome of the Van der Meer formula is rocks with a weight of 523 kg, than how should this outcome be interpreted? Should only rocks be applied that exactly weigh 523 kg? Should the rocks have a minimum weight of 523 kg?

Should the average rock weight be 523 kg, and if so, what should be the range (standard deviation) of the rocks.

THE ROLE OF A COASTAL ENGINEER IN A MULTI-DISCIPLINARY TEAM

Coastal engineering problems are often part of problems in coastal zone management. In addition to safety and protection, more functions of the coastal zone have to be taken into account. This implies that more disciplines are involved, like marine biology, water quality, landscape, demography, socio-economy. When planning works in the coastal zone it is therefore essential to have a thorough knowledge of the interaction between all the various functions intervening in the coastal zone. The coastal zone is not only the coastal strip, it also includes estuaries, tidal rivers and adjacent settlements, agricultural and aquacultural farmyards, as well as towns and coast related industrial complexes. Development plans, which affect the rivers and estuaries, also influence the coastal zone.

Post-graduate training of design engineers should also address these issues. A coastal engineer should understand the complexity of coastal zones and the role of coastal engineering in this field. In addition to understanding physical processes and mastering CE tools and formulas, our coastal engineer should also be capable to function in a multi-disciplinary team.

Including these requirements in an engineering course is far from easy. It is rather time consuming (thus in competition with the engineering part of the curriculum) and engineers are often not primarily interested in these 'soft' subjects. Our experience in Delft shows that:

- in-depth treatment of *non-engineering subjects* should preferably be done by coastal engineers with sufficient (theoretical and practical) background of these subjects, as specialists in areas like biology, economy, physical planning speak their "own, non-engineering language";
- transfer of *transferable skills* (like project management, report writing, presentation techniques, team role management, policy analysis, etc.) should receive ample attention in the curriculum;
- design engineers should be exposed to a multi-disciplinary environment through workshops, where they:
    - experience the importance of non-engineering aspects of a coastal zone;
    - learn to communicate with representatives of non-engineering fields;
    - formulate alternatives for complex problems including non-engineering aspects;
    - experience the 'ins and outs' of the decision-making process.
- Our yearly workshop on Integrated Coastal Zone Management may serve as example. This workshop is part of the CE curriculum of Unesco-IHE as well as a part of the M.Sc.-courses at Delft University (coastal engineering) and Utrecht University (earth sciences). The students of the Delft and Utrecht University are young students, with hardly any working experience, but with a good education in coastal subjects. The participants from Unesco-IHE have after their university studies in their own countries obtained at least three years of practical experience). In this course, participants experience that making an Integrated Coastal Zone

Management plan is one thing, but that implementation is of complete different order. For the Dutch students, it is revealing that the problems of their colleagues from developing countries are so different (difference in the decision making, degree of civil organization, effect of rules and regulations), and that Unesco-IHE participants have a rather modest contribution to discussions. For the Unesco-IHE participants it is revealing that the Dutch students have so little practical experience and are so dominantly present in a team and in the discussions.

INSTITUTION DEVELOPMENT

Transfer of CE technology also includes in increasing the number of locations where CE education is provided. This requires that in addition to training CE engineers, universities and institutes should be provided with sufficient staff and means to facilitate transfer of CE technology locally, for which a number of actions are required:

- training of trainers programs;
- upgrading curricula at universities to a masters level;
- upgrading university staff to PhD level.

THE PROBLEM OF SENIORITY

As mentioned above, young coastal engineers working in governmental organisations in countries in transition are often working with senior staff around them, not trained in modern coastal engineering. This means that they cannot learn the practical engineering skills from their older colleagues. And because in many cultures seniority is quite important in decision making, this may lead on one hand to relatively low quality decisions, but on the other hand also make it impossible for the young engineer to learn a number of things in practice. Given the cultural relevance of seniority in many countries, the only solution is to wait until our coastal engineer becomes a senior engineer. But in the mean time, this young engineer should learn the profession in practice. The best way of doing this, is by working in an environment with qualified senior engineers. Therefore it should be recommended to have exchange programs, in which young coastal engineers working for governments, will spend some time with the governmental service of a country with a coastal engineering tradition. However, language problems often prevent a good exchange of ideas.

CONCLUSIONS AND RECOMMENDATIONS

Transfer of CE technology at post-graduate level should aim at:

- development and improvement of conceptual thinking;
- increase the understanding of physical processes;
- increase the managerial capabilities of the course participants;
- understand the role and importance of coastal engineering within coastal zone management.

A sustainable transfer of CE technology at post-graduate level to engineers should comprise:

- personal contact with a relatively high number of experts;
- practical oriented curriculum, covering the many components of coastal engineering(which is more than only factual knowledge);

- exposure to different cases in different situations (physical as well as social/cultural);
- integration of all CE components.

Realizing a successful transfer of technology implies an intensive guidance of both the engineers attending such training as well as their trainers.

REFERENCES

HILDEBRANDO DE A. GÓES FILHO [1995] Profile of the new coastal and port engineering technician at the end of the 20th century; *Invited Paper, Copedec IV*, Rio de Janeiro, Brazil

KOBUS, H., PLATE, E., HSIEH, WEN-SHEN, SZÖLLÖSI-NAGI, A. [1994] Education of Hydraulic Engineers; *J. of Hydraulic Research, vol32, nr2, pp 163-181*

VERHAGEN, H.J. [1995] The requirements for Coastal Engineers in Integrated Coastal Zone Management; *Copedec IV*, Rio de Janeiro, Brazil

VERHAGEN, H.J. [1996] Education of coastal engineers for the 50th ICCE, *proc. 25th ICCE, Orlando, USA, ASCE*

Old Dominion Website [2005] http://www.cee.odu.edu/~basco/