WEB-BASED DECISION SUPPORT SYSTEM FOR INCORPORATING GEOSYNTHETICS IN COASTAL PROTECTION WORKS

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Abstract: Geosynthetics are becoming essential components of coastal structures, as there are various possible applications for these materials in coastal defence works. Actually, geosynthetic solutions have been successfully applied in a number of projects around the world, and their use as erosion control measures has shown several capabilities. With the improvements achieved at the level of the materials and the growing interest in the development of innovative techniques of coastal defence, these measures are evolving towards becoming a real alternative to traditional solutions, especially under mild wave climates.

Despite the benefits provided by the use of these systems, related to their low cost, simplicity in construction and minimum environmental impacts, there is still a lack of knowledge concerning the design tools and the long term performance, especially under more exposed conditions. Moreover, with respect to the application of geosynthetics in coastal engineering, most of the information is scattered and in most cases it is difficult to have access to all the data required. These issues have prompted the development of a comprehensive Decision Support System (DSS), concerning the incorporation of synthetic fabrics in coastal protection works, with especial emphasis on aspects related to the performance of existing defence structures.

The paper will describe a Web-Based DSS, developed as a part of an ongoing research project on the experimental stability analysis of geotextile containers under wave loading, pointing out its requirements, limitations and capabilities. The DSS was developed in PHP and PostgreSQL, with a user-friendly interface, created to facilitate the data access and visualization. This tool aims to improve the decision making process in view of the possible incorporation of synthetic fabrics in coastal protection works as it allows a comprehensive understanding of the feasibility and performance of this kind of solutions.

Keywords: geosynthetic, coastal erosion protection, data base.

INTRODUCTION

The development of soft coastal engineering solutions using geosynthetics has grown in interest in recent years, following the improvements achieved at the level of the materials and the lower acceptance of some of the common protection devices, due to environmental and visual impacts. Along with this, the benefits associated with the incorporation of geosynthetics in coastal protection works, namely low cost, minimum environmental impact, high effectiveness, simplicity in placement, construction, as well as, reversibility when necessary, are contributing to the competitiveness of these solutions when compared to traditional ones. This competitiveness is particularly significant in areas where the capital at risk is low due to non-existence of endangered important urban seafronts.

However, there are drawbacks to the application of these protection devices. These concern the design tools available and the unknowns related to their performance and stability on the long run, especially at more exposed sea conditions. Additionally, it can be difficult to find information on lessons learned from past experience. For most cases the information is scarce and difficult to access.

This paper describes a Decision Support System that has been designed to aid decision-makers who deal with the incorporation of geosynthetics in coastal protection works, with basis on the experience gained from past experiences, the results from physical modelling and the existing technical and constructive recommendations.

The DSS has been created as a part of an ongoing research project, running since September 2005, which aims to investigate behaviour of geotextile sand-filled containers in dune erosion control systems, when submitted to extreme wave conditions (das Neves *et al*. 2008). The study will be based on the results obtained from model tests performed at two different scales, at the Faculty of Engineering of the University of Porto and at the University of Coruña, and field studies carried out in the Portuguese northwest coast.

The development of this DSS was driven by two main ideas. The first was that it should serve immediately the purposes of the ongoing research, hence it integrates applications of geosynthetics in coastal protection works that are reported in literature, results from research programmes and other available information, in a way that is systematic and easy to have access to. The second was that it should be an interactive, flexible and adaptable computer-based information system, easy to update and upgrade.

This paper will present an overview of the developed DSS prototype version design. Attention will be focused on survey data, architecture, system features and functions of this tool. Finally a discussion is made on further developments.

GENERAL DESCRIPTION

Introduction

As a complement to planning and design procedures, Decision Support Systems (DSS) enhance decision making, by providing faster and better access to relevant and comprehensive information. Broadly speaking, a DSS can be defined as computer-based tools used to support complex decision making and problem solving (Power and Kaparthi 2002, Shim *et al*. 2002). A DSS does not replace any subjective judgement but gives a clear framework to rank and choose between options.

As it is here presented the developed DSS is a set of computer based tools that provide decision-makers with interactive means to enhance understanding and knowledge base trough the use of data structuring and processing. It permits accessing relevant information in a faster and better way but does not substitute personal knowledge and judgements.

It is able to manage, retrieve, summarize and manipulate structured and unstructured information in a variety of electronic formats. Standards, product specifications and images are examples of types of documents accessible to users. The support for decision making is given by electronically keeping track of textually represented knowledge that can have a bearing on decision. To enable this, a search engine was developed, providing a powerful decision-aiding tool to the application.

In addition, this DSS provides specific problem-solving expertise stored as facts, rules, procedures, recommendations and lessons learned. The "expertise" consists of knowledge about the incorporation of synthetic fabrics in coastal protection works stored and structured in a PostgreSQL database.

The development of this tool was carried out within the following five phases:

- State-of-the-art research;
- Data analysis and structuring;
- Technology analysis and selection;
- Database development;
- Web site development.

Architecture

The Web-Based DSS described in this paper was built using a three-tier architecture: a person using a web browser sends a request using the hypertext transfer protocol (HTTP) to a web server; the web server processes the request, using a script; the script processes a database request; and, finally, the results are returned to the user's web browser for display (Figure 1). This web application was designed to allow any authorized user, with a web browser and Internet connection to interact with it.

There are two main components within this DSS: the data management system; and the user interface. The first component is where the information is stored and it is basically a database developed in PostgreSQL. PostgreSQL is a powerful relational database management system, designed for environments where a great amount of data exists. The user interface was developed in PHP (hypertext pre-processor). PHP is a HTML embedded scripting language especially suited for web development. Both PHP and PostgreSQL are open source technologies.

The Web-based DSS here described was tested to run in Windows operative system, using Apache Web Server for Windows and PostgreSQL for Windows.

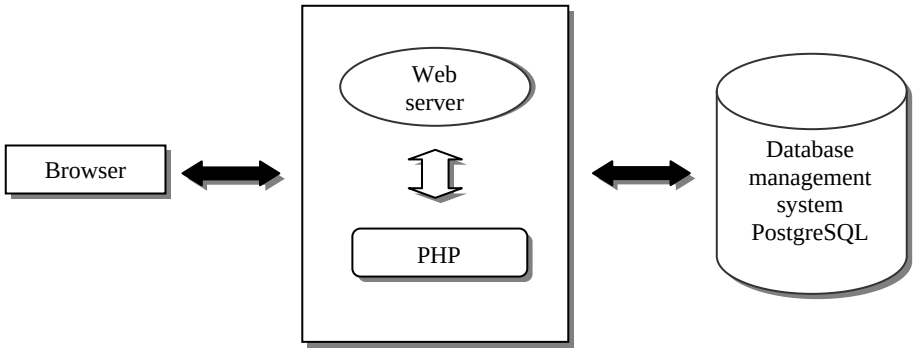

Figure 1. Architecture.

Survey data

The first step when building a data management system consists in clearly identifying the relevant data for storing, visualization and processing. In regard to the database developed, the information inserted relies on four main categories of data: coastal structures; physical model tests; numerical and mathematical models; and finally, geosynthetics. Going further on each category:

- Coastal Structures: it is evident that one of the categories would be this one; there are various successful applications of geosynthetics in coastal protection and, on the contrary, less successful ones from which one can learn more; the database allows the storing of information on existing coastal structures; this comprises,

for instance, a brief description, type of structure, year of construction and builder, geographic area, lessons learned and possible remarks; images and other relevant documents can be uploaded as well.

- Physical Model Tests: physical model tests provide relevant data when studying a particular problem; in the past few years some research on the application of geosynthetics in coastal protection using physical modelling was carried out and some important results were delivered; the database enables the storage of all sorts of data concerning laboratory experimentation, as a brief description of the test, the type of coastal structure, model scale (or various scales), test conditions and instrumentation, results and outlook.
- Numerical and Mathematical Models: this type of models for this type of applications is not well developed; nonetheless, as in other fields it can be an important support for decision making and is therefore a built-in category; the database allows the storing of all sorts of data related to the use of numerical and mathematical models in simulating the incorporation of geosynthetic in coastal protection works.
- Geosynthetics: this is again an evident category of data, which comprises full records on frequently used geosynthetics in coastal applications; *inter alia*, designation, description, type of geosynthetic, functions, manufacturer, properties and standards.

For all the above mentioned categories, full references are uploaded to the database. Additionally, information is, as far as possible, given in Portuguese and in English.

System features

The developed Decision Support System can perform the following functionalities:

- Visualization of the data both in Portuguese and English;
- Users authentication, with different levels of permission;
- Information searching;
- Inserting new data;
- Updating existing data;
- Deleting existing data.

In order to run properly, the software must also satisfy non-functional requirements related to:

- Feasibility: this tool was designed to be used by different profile users. For that reason, an easy to learn, user-friendly interface was developed within it. As it is a web tool, compatibility with common internet browsers (*Internet Explorer*, *Netscape Communicator*, *Opera*, *Mozilla Firefox*) is oblige;
- Reliability: it is intended that the developed DSS becomes a useful tool for designers and researchers. Thus, information provided by the software must be reliable, without inconsistencies or errors. On the other hand, data must be protected by a trustworthy security system, to avoid non-authorized accesses;
- Performance: since the software was created as a web tool, the system speed is an important aspect;
- Maintenance: in the future, system updates may be necessary. To enable this, proper documentation must be provided, allowing the maintenance of the system by a common programmer.

Modules

With respect to contents, the DSS is currently divided in three modules – Existing Coastal Defences, Case Studies and Experimental Studies (physical and mathematical modelling) – organized according to the type of coastal structure (Figure 2). A fourth module, concerning design tools and methodologies, is now under development and it is anticipated that other modules will also be included in the DSS.

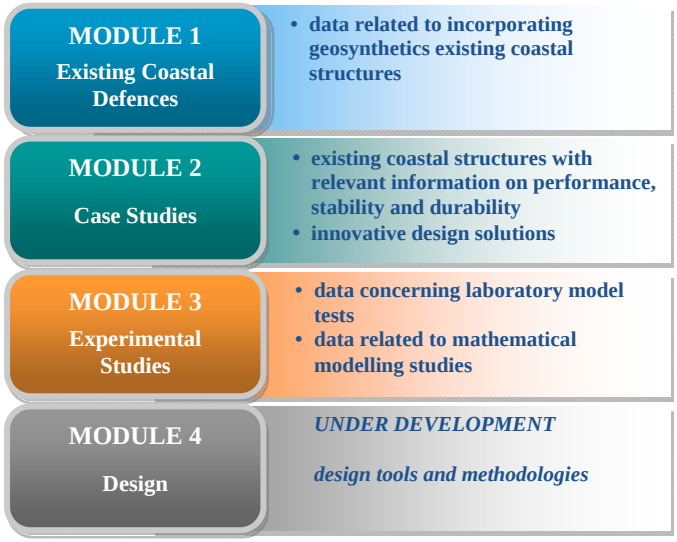

Figure 2. Current modules scheme of the DSS.

The module on Existing Coastal Defences includes data related to incorporating geosynthetics existing coastal structures. In this module, users can search for geosynthetic application examples.

The second module refers to case studies: existing coastal structures that provide relevant information concerning performance, stability or durability of structures and also design solutions for the construction of new structures. The main difference between this module and the previous one relies on the amount of data available for consultation. A case study presents a more comprehensive description of the selected coastal structure.

Finally, the third model concerns experimental studies; laboratory model tests and mathematical modelling studies used to simulate the incorporation of geosynthetic in coastal protection works.

User Interface

The user interface is the vehicle of interaction between the user and the computer. It enables the user to address the different components of the DSS, translates the user input into appropriate computer instructions and reports back the results of the computations. Another important role of the user interface is to hide the complexities of the internal computer system without hampering its flexibility.

The user interface of this DSS is currently available as a prototype version, which will differ to the final version; Figure 3 shows a screen shot of the introductory page. As one can notice in the figure, it is a user friendly and easy to learn web-based DSS. A drop-down menu is available on the left hand side of the screen and can be used to navigate through the following datasets:

- Coastal Structures: provides general information on different types of coastal protection works;
- Geosynthetics: provides general information associated with geosynthetics (*e.g.* properties, functions, standards);
- Coastal Structures Incorporating Geosynthetics**:** where users can access data concerning the incorporation of geosynthetics in coastal protection works; it incorporates the three modules – Existing Coastal Defences (Module 1), Case Studies (Module 2) and Experimental Studies (Module 3);
- Contacts: provides relevant information about builders, manufacturers and laboratories;
- References;
- Glossary;
- Search Engine: where users search the database using oriented search forms;
- Data Editing: where users can manipulate data;

Figure 3. Screen shot of the introductory page.

APPLICATION

As mentioned before, this Web-Based DSS was designed to give researchers, designers and other stakeholders access to relevant datasets for answering complex questions when incorporating geosynthetics in coastal protection works. In this context, pertinent questions will turn around, for instance: *"How can a temporary solution be enhanced towards becoming an effective measure in a medium to long term basis? Should the improvements be taken on the level of the materials or of the design (or both)?"*

The decision-making processes associated with the planning and design of coastal protection works are rather complex, requiring very thorough consideration and analysis. Reaching a final solution that meets all functional

criteria and satisfies stakeholders' aspirations, involves an interactive step-wise process (Housley and Thompson 2006). This process consists in determining, at each step of the process, whether the objectives of that step are met. This is achieved by means of a generic chart where the questions are answered either "*yes*, it meets the objective" (go on to the next step) or "*no*, it does not meet the objective" (go back and either refine the question or pick another alternative). Detailed answers to: *"What is the problem?"* and *"What exactly is the project trying to accomplish?"* have to be collected beforehand.

Considering the interactive, step-wise process described above, one can distinguish three phases:

- the identification phase. In this phase, a better understanding of the true nature of the particular problem is searched. During this phase, one first tries to focus the causes behind the problem before focusing on solutions for it.
- the development phase. In this phase, solutions to the recognized problem have to be found and a large number of alternative solutions are designed and searched.
- the selection phase. In this phase, the best solution for the problem is found among all the possible solutions.

The current version of the DSS offers support for mainly the identification and the development phases. The selection phase is supported to a lesser extent. This can be improved when fully developed the fourth module, concerning design tools and methodologies.

For a particular coastal engineering problem, the DSS would be able to provide knowledge expertise concerning coastal structures and geosynthetic materials. This capability is quite useful because information on geosynthetics in coastal engineering related issues is generally scarce and experts rarely cover both fields. Hence, "knowledge management" on coastal structures and geosynthetics in imperative and still needs further development.

Another way that this tool can help decision makers is by providing detailed and comprehensive descriptions of the construction area (including physical and socio-economical factors). Obviously this process is largely driven by information needs and data availability. In addition, the DSS enables the storage of relevant data for further analysis, for example, in the one attained through monitoring campaigns.

Summing up, the main capability of this DSS relies on its search engine that allows decision makers to find useful information within the available modules. For a given input at the search form, users will obtain, within the first module, a list of the possible existing coastal structures that match the selected search criteria and within the second one related case studies. Figure 4 shows the output list for a search on Existing Coastal Defences (Module 1) with the input *"beach"*. Browsing within these two modules, the decision maker will be able to learn with the experience gained from past applications, particularly if information on lessons learned, remarks and performance of the coastal structures is available.

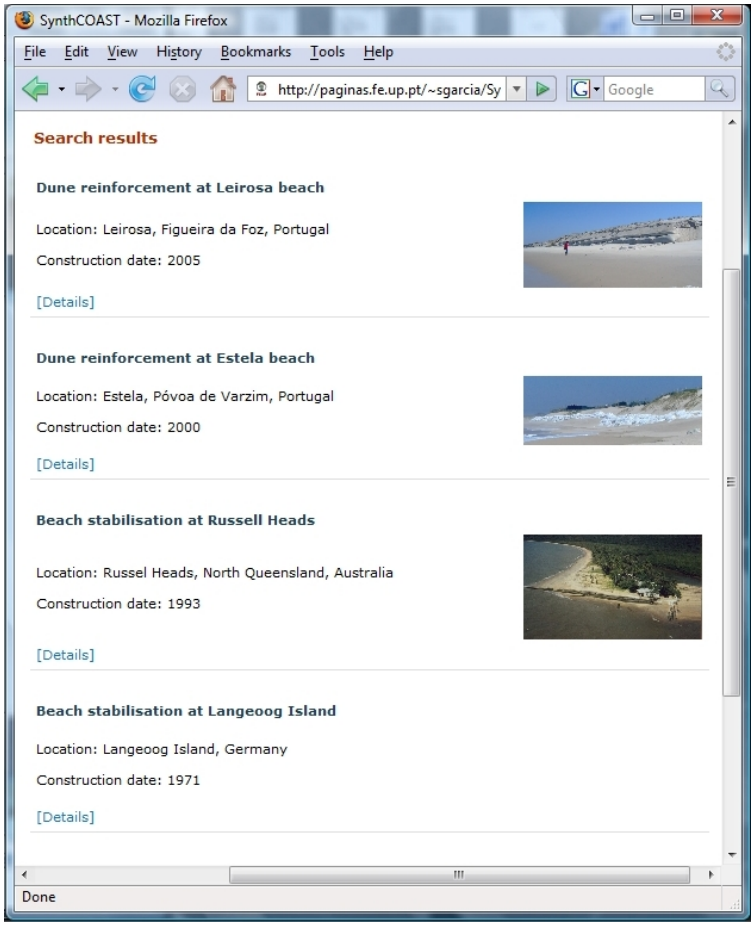

Figure 4. Output list example for a search on Existing Coastal Defences with the input *"beach"*.

The third module is not quite suited for supporting design problems, as it was designed to serve immediately the purposes of the ongoing research project. Hence, it incorporates useful project and construction recommendations delivered from experimental studies and it works as a base for the development of the fourth module concerning design tools and methodologies. Figure 5 shows a laboratory test study that can be found in the database contents: *"Placing accuracy and stability of geocontainers"* (Bezuijen *et al.* 2004, Bezuijen *et al.* 2000, Bezuijen *et al.* 2002a, Bezuijen *et al.* 2002b).

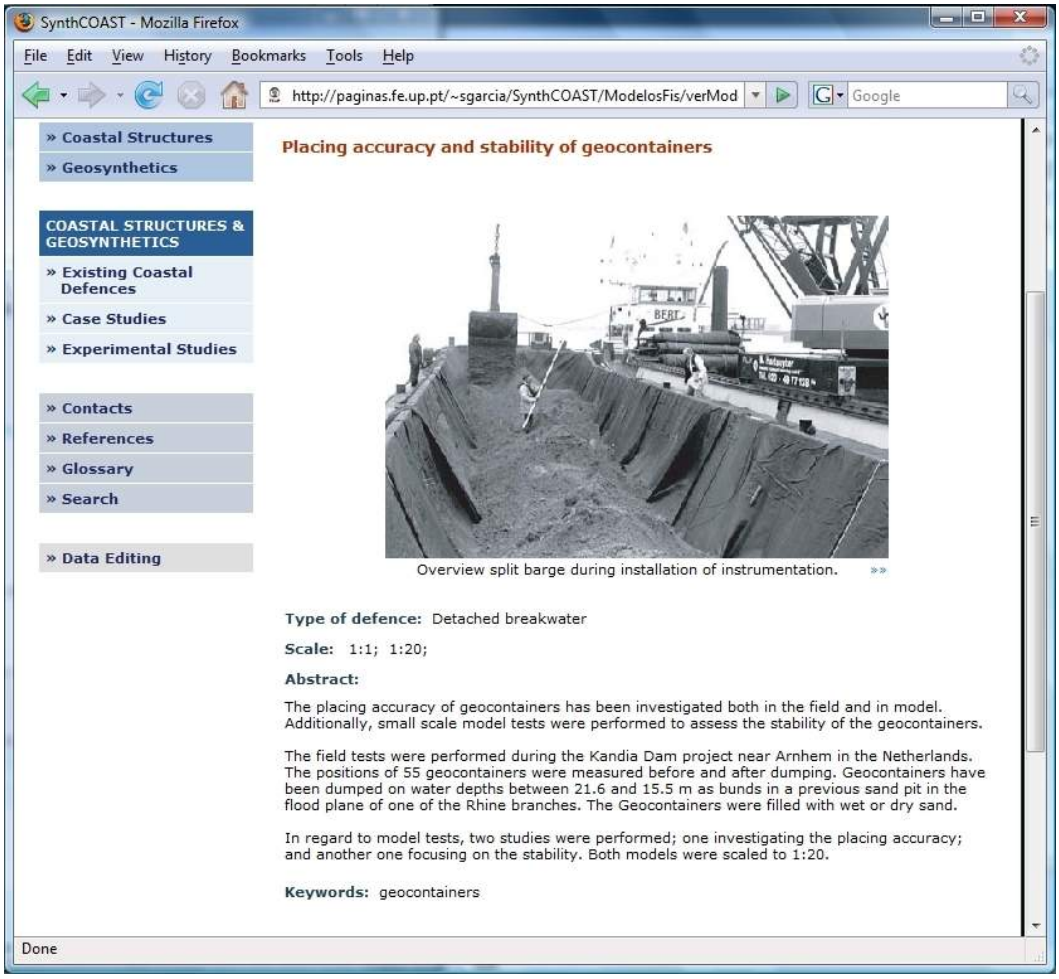

Figure 5. Database contents: laboratory model test example.

This section was only meant to gain insight into the capabilities and the potential of the DSS as a tool for improving the decision making associated with the incorporation of geosynthetics in coastal protection works. The system is not yet fully developed and is of course highly dependent on the accuracy of the available data. Another potential applicability of the system is using it as a training toll for users less familiar with the incorporation of geosynthetics in coastal protection works.

CONCLUSIONS

Decision-making processes related to the planning and design of coastal protection works are rather complex, involving both objective and subjective judgements.

Developed within a research project, this Web-Based DSS was designed to facilitate the decision making associated with the incorporation of geosynthetics in coastal protection works, following the lessons learned from past experiences, the results from physical modelling and the existing technical recommendations. Given that every coastal engineering problem is different, this DSS was developed to provide general guidance and to promote general principles rather than provide absolute answers.

The system is founded on robust open source elements that are assembled in accordance with software architecture. These features should ensure that it will endure, providing a long lasting, robust, extensible tool essentially for use by designers and researchers. This inherent flexibility also allows considerable scope for extension and modification to suit a range of other sorts of data, namely design tools and recommendations.

In order to improve data quality, feasibility and reliability, considerable efforts must be spent to optimise the design of the database, to create a detailed user manual and, above all, to feed the database with comprehensive data on case studies.

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