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Building with sand – simple outreach activities to promote GeoEngineering

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SUMMARY: This paper describes two sets of simple outreach activities, designated as “Building with sand”, promoted in Portugal or in the UK. The hands-on activities focused on reinforced soil, using sand and paper. The activities included: 1) 30 minutes’ sessions in a Geotechnical laboratory (UK) in which participants build small cylindrical samples of reinforced and unreinforced sand and compare their resistance; 2) 3 hours’ sessions where students are challenged to build and load small reinforced soil structures (Portugal). For the latter, in 2011/2012 pre- and post-activity questionnaires were used, focusing on the students’ learning and perceptions/opinions. The activity organised was clearly a success for both the learning and the impact on the students participating. The results from the questionnaires indicate that with this activity it was possible for students to grasp complex concepts on soil strength and soil reinforcement. For both sets of activities the required resources were limited, making them easily replicable. The activities are easily adaptable to different audiences, which can range from K-12 students to graduate students.

KEYWORDS: outreach, open days, basic concepts, students perceptions, active learning.

1 INTRODUCTION

The international technical and scientific community is becoming more aware of the need for promoting and attracting students to GeoEngineering. The future of geotechnical education may rely on such initiatives.

This paper describes simple activities that have been used successfully in the past years in outreach events. Items normally available in a geotechnical laboratory (sands, trays and small tubes) have been used, complemented by stationery, such as old office paper, scissors and tape, and, in some cases, plastic containers. Different activities have been implemented by the author in Portugal and in the UK, with different target groups, durations and objectives.

The activities can be replicated easily and they can be used to reach different audiences and to promote Geotechnical Engineering.

2 SCOPE

Universities have been trying to increase the outreach and attractiveness of engineering degrees. Many institutions run and fund programmes focused on increasing recruitment and on promoting awareness of careers in science, technology, engineering and mathematics (STEM) fields.

Open days, allowing the community to become aware and getting involved in scientific work under development, are good examples of engaging the community in STEM activities in universities. For example, the University of Aveiro (UA) in Portugal has been successfully organising science and technology open weeks in November and Summer Academy in July since 2000 and 2006, respectively.

3 BACKGROUND

The use of outreach activities, particularly in engineering, has been increasing around the world. Many of the reported activities are school-based (Smaill 2010). Outreach activities have been developed with two main goals: to promote the increasing interest in STEM fields;

to address gender and technology related stereotypes. From the comparison between eight European initiatives promoted and run by universities, Gumaelius et al. (2016) identified two main trends for creating outreach activities: 1) extending the university's normal activities; 2) activities specifically designed for the visiting students.

The activities reported in the literature include competitions, shows, school programmes and recruitment activities. This wide scope ranges from simpler forms (e.g., developing web and classroom material) to more complex ones (such as organising professional development programmes and engineering contests), sponsoring teaching fellows and service learning programmes (Jeffers et al. 2004). Depending on the intended target group (whether it is more generic, including teachers and/or students, or more specific, eg. focusing on females or minorities), the outreach activities need to be adjusted.

Well managed outreach activities that link universities and secondary schools are beneficial for both institutions (Smaill 2010): the number of better-prepared students applying to the university is likely to increase; and the secondary students and/or their teachers can have an enriching experience.

In the literature it is possible to find some guidelines for improving the quality, the methodology and the engagement of engineering education in schools. These include (Dawes and Rasmussen 2006):

- hands-on learning
- interdisciplinary approach by including technology
- promote relations with mathematics and science
- engage teachers and update curricula
- improve the image of engineers
- promote partnerships.

Additional advantages of outreach activities include: encouraging dialogue between university students and both secondary students and teachers; secondary students perceiving the academic life of an engineering student; promoting interpersonal and communication skills of university students, and (in some cases) creating an additional income for them.

Some authors have reported outreach activities on geotechnical engineering. Elton et al. (2006) discussed educational outreach activities designated the Soils Magic show. The authors tried to relate the students' engagement on the activities with their choices to study civil engineering, or engineering in general. Soils Magic focus on geotechnical engineering and initially was developed for laboratory sessions for undergraduate students. Later the activities were revised to suit students of ages between 4 and 19 years (K-12) to enable demonstrating the principles of soil mechanics. The "magic" is associated with the unexpected results of the experiments (Elton et al. 2006). The success (for both participation and learning) seems to be also associated to some characteristics of the experiments, which are simple, can be related to real engineering problems and are hands-on (particular important for younger students). The adaptability of the programme was found key to its success, as it can be adapted for different audiences and timetables.

4 THE INSPIRATION

The activities reported in this paper ("Building with sand") were initially designed for assisting teaching and learning on reinforced soils (Pinho-Lopes, 2016). The first inspiration came from the Geo-Challenge, sponsored by the Geo-Institute of ASCE (American Society of Civil Engineers). This is a set of student competitions (undergraduate and graduate civil engineering students), which tries to "engage students in technical and important nontechnical areas of professional development" (Cerato et al. 2012). Its purpose is to develop teamwork skills, design experience, and communication skills.

In the U.S.A. national competition (which started in 2005) students build model retaining walls in a competitive environment. The competition has been defined in order to keep it "simple, inexpensive, not too time-consuming, and requiring a minimum number of tools" (Cerato et al. 2012). Nevertheless, its technically challenging character is essential, while incorporating the use of other skills (engineering judgment, writing skills, creativity, leadership, teamwork) and being able to enthusiasm students.

Although the rules are adapted in each edition, the basis of the competition is always the same: the aim is to build a mechanically stabilized earth wall using sand (dry and clean) and paper reinforcement. The wall will have to hold a specified load (axial and/or lateral) for a defined period of time without evidence of excessive deflections, loss of sand, or failure. The models are built in a wooden box ($66 x 45.7 x 45.7 \ cm^3$), with one removable side.

5 ACTIVITIES

The outreach activities organised have been pitched to match the level of knowledge of their target audiences. Two different sets of activities, identified as "Building with sand", were designed:

1) A hands-on activity in the geotechnical laboratory (~30 minutes) used to illustrate concepts such as angle of repose, pore water pressure, and soil reinforcement. This activity was held at University of Brighton (UB), UK.
2) A 3 hours' session where participants are challenged to build soil reinforced structures using sand and paper (as reinforcement). This was implemented at University of Aveiro (UA), Portugal.

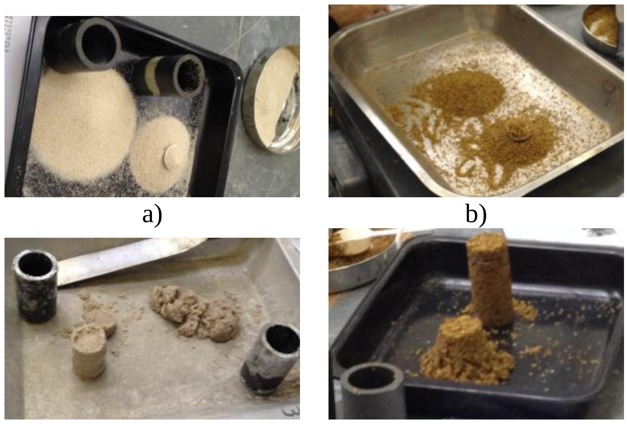
5.1 Building with sand – 30 minutes' session

The first group of outreach activities described herein includes open days targeted at potential applicants at university programmes, organised at University of Brighton, UK. These events focus on recruitment. The participants are potential applicants who have not decided on which course / university to apply for.

Figure 1 illustrates the materials used for the hands-on activities using sand and paper. During the session, the students built cylindrical samples of soil using two types of sand, both dry and with some moisture. Similar samples were built adding horizontal layers of paper reinforcement. The strength of unreinforced and reinforced samples was compared by removing the casing (plastic cylinder) and, in some cases, applying some load. Figure 2 illustrates some of the experiments performed.

a) b)

Figure 1. Materials used, such as cylinders, a) coarser sand and paper and grid reinforcement; b) finer sand.



a) b) c) d)

Figure 2. Cylindrical reinforced and unreinforced sand samples: a) finer sand, dry; b) coarser sand, dry; c) finer sand, wet; d) coarser sand, wet.

Although most participating students were enthusiastic, their level of engagement varied, depending on several factors (for example, their personality and the group dynamics). Nevertheless, most students were curious and after some "ice-breaking" most of them had a go at building the samples and wanted to understand how reinforcing soil was relevant for "real world" projects. The informal feedback from both the students and their accompanying person(s) was very positive.

The activity had other implications, as it also engaged the student ambassadors attending such sessions. These are students on the Civil Engineering undergraduate programme, who are paid to work as helpers on these events. The feedback from this group was so positive that later this type of activity was included in one of the modules on Soil Mechanics, as an introduction to sessions in the laboratory.

5.2 Building with sand – 3 hours' session

The 3 hours' session "Building with sand" was designed as a stand-alone activity for both Science and Technology Open Weeks and for the Summer Academy programmes "How the world is built", organised by the Civil Engineering department of University of Aveiro, Portugal. The guidelines presented by Dawes and Rasmussen (2006) and the recommendations by Elton et al. (2006) were taken into consideration in that process.

The main driver when designing the activity was to attract secondary students, engaging them in a simple project that would make use of the active learning models used in the Civil Engineering integrated masters at UA. The participants would also be exposed to research activities, become aware of their applicability and relevance on the daily life of the wider community, and discuss sustainability issues.

The activity was designed to be versatile and easily adapted to suit audiences with different ages and backgrounds, and allow offering it to groups with no previous knowledge on soil mechanics.

5.2.1 Outline

During this activity students build reinforced soil walls using paper as reinforcement. The activity, which lasts around 3 hours, is divided into different moments:

1. Short presentation on the topic;
2. Tour around the geotechnical laboratory;
3. Build the models in teams;
4. Load the models and compare their performance;
5. Discuss the results and brainstorm to explain observed differences in behaviour.

The activity takes place in the laboratory of Geotechnics of the Civil Engineering Department of UA. The space is cleared and organized to allow students to move around (without disturbing on-going tests) and they are encouraged to do so. The number of participating students is limited to 20. They are welcomed by the author and a group of research students (M.Sc. and/or Ph.D.). A short presentation on the topic of reinforced soil is made, in which students have an active role. They are questioned, handle samples of geosynthetics and ask questions. The activity and what is expected from them are also briefly summarised. The presentation promotes discussions on the strength of soils, on the need for soil reinforcement and on the role of such elements. The concepts of soil friction and cohesion are dealt with using every day physical examples to illustrate them. After analysing how reinforced soil structures are built and how they sometimes can be identified visually, students are asked to list construction works near their schools were reinforced soil may have been used.

The large group is then divided into four teams of five students and each group is separately toured around the laboratory, having the chance to better understand the on-going tests. The teams manipulate soil samples and compare the behaviour of dry and wet samples of sand by filling in and turning over small containers full of either material. The concept of apparent cohesion is discussed and students are asked to predict what would happen if the wet sand was allowed to dry.

For the 3rd moment of the activity each team is directed to their working area, where a plastic container, sand, pouring material, wooden plates to compact the soil, old and used office paper and scissors are available (Figure 3). For each team the reinforcement type, length and density is previously defined, in order to ensure different behaviour can be observed when the models are loaded. The structures have some layers built previously, to ensure each team is able to complete their structure in the allocated time. Each team has to finish building their model following the constructive sequence of a real structure: spread the soil, level and compact it, place the reinforcement material (fixing it to the facing system when relevant). These tasks are repeated until the final desired height of the models is achieved (Figure 4).

a) b) c)

Figure 3. Small scale models: a) plastic containers where the models are to be built; b) wooden plates for soil compaction; c) facing in paper and strips of reinforcement; d) paper grid reinforcement.

a) b) c)

Figure 4. Examples of small scale models of soil reinforced structures: a) model completed with continuous (sheet) reinforcement; b) example of strip reinforcements; c) loading of a finished model.

When all teams finish their models, the large group is gathered, so the loading phase can start and the response of the models is observed and registered. Each team explains how the model was built, describing the reinforcement type (strip, grid or continuous), the vertical and (when relevant) horizontal spacing between reinforcement elements. That data is summarised on a white board. Then, each model is progressively loaded, when possible, until failure. Different failure modes are observed: sliding along the base, tensile rupture of the reinforcements and failure by pull-out on the upper layers of reinforcement. Often the teams are quite competitive, anxious to see how their models perform. In most cases, the teams with the best models (that do not fail) are very disappointed.

After each failure, the observed response and their causes are discussed and possible ways of preventing them are put forward by students. At the end, the author makes a brief summary.

5.2.2 Impact and assessment

This activity was implemented for the 1st time in 2009. Students on that group were very enthusiastic. The teacher accompanying the group gave very positive feedback on how the students engaged and learned from the activity; later editions had similar feedback.

In 2011/2012 the impact of the activity was assessed more systematically, using pre- and post-activity questionnaires. These focused on key concepts on reinforced soil and on the overall perceptions of students.

A short and simple questionnaire was designed. The main aim was to assess the influence of the activity on learning of complex topics. A set of five questions (Table 1) on the topic was given to students before and after the activity. The possible answers were “yes” (Y), “no” (N) and “I do not know” (D). The questions covered topics that were dealt with during the activity (in one or more of the five moments described).

Question Q1 aimed at assessing if students were paying attention when answering the questionnaire. As the title of the activity they had enrolled in was “Building with sand”, their answer should be immediate and obvious.

The post-activity questionnaire had two additional sections: a set of five questions on the organisation of the activity (Table 2), where a Likert scale was used (ranging between 1, lowest, and 5, highest); and an open question asking for comments and suggestions.

Table 1. Questions used on both the pre and post-activity questionnaires (possible answers – yes, no, I do not know).

No.	Question
Q1	Is soil a building material?
Q2	Does sand have tensile strength?
Q3	Is dry sand stronger than the same sand wet?
Q4	In a reinforced soil structure do reinforcements bear tensile loads?
Q5	For the stability of such structures should reinforcements be as short as possible?

Table 2. Questions on the organisation of the activity (answers ranging between 1, lowest, and 5, highest).

No.	Question
Q6	Did this activity help you learn new things?
Q7	Was the activity interesting?
Q8	Was the activity well organised?
Q9	Would you recommend the activity to your friends?
Q10	Did you enjoy building the structures?

4.2.3 Informal feedback

The informal feedback received after several editions of this activity, from both participating students and their teachers, has been overwhelmingly positive. Consistently they said they enjoyed the activity and have learned new concepts while having fun.

It is interesting to see that some students are a bit frustrated as their structure performs well during the loading phase and does not fail. For most students the true thrill is to actually see failures.

From another perspective, the helpers (Ph.D. and M.Sc. students) have always been very enthusiastic. Depending on when the activity takes place, some of them have just prepared similar models for their coursework on an elective module on Application of Geosynthetics in Civil Engineering (Pinho-Lopes 2016). The helpers supported the participating students, explaining concepts, relating the activity and the scaled models with real-scale structures. Additionally, the participating students often interact with the helpers, asking them how the Civil Engineering programme is and if they normally do similar activities. This interaction is very interesting and it is an excellent promotion of the programme and of the teaching and learning resources used. Moreover, the helpers further develop their communication skills and consolidate their own knowledge on soil mechanics and reinforced soil.

4.2.4 Pre- and post-activity questionnaires

The pre- and post-activity questionnaires (one A4 paper sheet) were used in 2001/2012, with the participation of twenty students. The pre-activity questionnaire (1st page) was handed out after welcoming the students and answered immediately. At the end of the activity students filled out the post-activity questionnaire (2nd page). This enabled keeping track of the answers of each student before and after the activity, which in turn allowed assessing the influence of the activity on the learning of each student. The answers of all the students are included in Table 3, before and after the activity. Table 4 summarises the results obtained for the questions used in both questionnaires.

Apparently students took the pre-activity questionnaire seriously, as most of them (85%) answered Q1 correctly and 10% said they did not know the answer. A significant proportion of students answered “I do not know” (D) to Q2 – Q5 (40%, 15%, 45% and 30%, respectively) and a majority of students gave the expected answer to these questions: 55% for Q1, 75% for Q2, 50% for Q3, 50% for Q4 and 45% for Q5.

Table 3. Results of pre- and post-activity questionnaires.

Question		Participant																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Q1	Pre	Y	Y	Y	Y	D	N	Y	D	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q2		Y	N	N	N	D	N	D	D	D	N	D	N	N	N	D	N	N	N	D	D
Q3		N	N	N	N	N	N	N	N	Y	Y	N	D	N	N	N	N	N	N	D	D
Q4		N	Y	Y	Y	Y	Y	D	Y	D	D	D	Y	D	Y	D	D	Y	Y	D	D
Q5		Y	N	N	Y	Y	N	D	Y	N	N	N	D	Y	N	D	N	D	N	D	D
Q1	Post	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q2		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Q3		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Q4		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q5		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y
Q6		5	5	4	4	5	5	5	5	4	4	4	5	5	5	5	5	5	5	5	5
Q7		5	5	5	4	5	5	5	5	5	5	4	5	5	5	5	5	4	4	5	5
Q8		5	5	5	4	5	4	5	5	5	4	5	5	5	5	5	5	4	4	5	5
Q9		5	5	5	4	5	5	5	5	4	3	5	5	5	5	5	5	5	5	5	5
Q10		5	5	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5

Pre – pre-activity questionnaire | Post – post-activity questionnaire | Y – Yes | N – No | D – I do not know

Table 4. Summary of results of the pre- and post-activity questionnaires.

Question	Pre-activity No. of answers			Post-activity No. of answers		
No.	Y	N	D	Y	N	D
Q1	17	1	2	20	0	0
Q2	1	11	8	0	20	0
Q3	2	15	3	0	20	0
Q4	10	1	9	20	0	0
Q5	5	9	6	2	18	0

Y – Yes| N – No | D – I do not know

The trend in the answers to the same questions are clearly different after the activity. All students gave the same answers to Q1 to Q4, showing that the learning outcomes were achieved. For Q5 there were 2 students (10% of the total) who were not clearly aware that increasing the length of the reinforcement contributed to the stability of reinforced soil walls. Those students (19 and 20) were quite honest on the pre-activity questionnaire by saying they did not know the answer to Q2 to Q5.

There can be a bias factor on the answers after the activity took place, as students already were aware of the questions and could have been taking particular attention to their answers. If this was the case, using the questionnaires has further contributed to promote learning.

Table 5 summarises the answers referring to the organisation of the activity. As it was evident from the informal feedback, all students found the activity was a significant help to learning new things (75% students gave the highest score) and was very interesting (80% students gave the highest score) and very well organised (75% students gave the highest score). One of the students seemed neutral as to recommending the activity to friends and colleagues while the remaining 19 students clearly would do it (85% students gave the highest score). All students said they enjoyed building the structures (90% students gave the highest score).

Table 5. Summary of results on the organisation of the activity (answers ranging between 1, lowest, and 5, highest).

No.	Low		Medium		High
	1	2	3	4	5
Q6	0	0	0	5	15
Q7	0	0	0	4	16
Q8	0	0	0	5	15
Q9	0	0	1	2	17
Q10	0	0	0	2	18

Five students also included some comments on the open question:

- Student 1: “I adored everything. It was very interesting and, besides learning new things, we had lots of fun”.

- Student 14: “It was nice, but I am sorry there weren't enough loads to make all structures fail (except the one we built)”.
- Student 15: “It was a good team work as, besides fun, we worked as a team and without problems. For those who questioned our work, our structure was one of the best, as it didn't fail easily”.
- Student 19: “It was a beautiful work.”
- Student 20: “I am speechless. I really liked it.”

These comments confirm the informal feedback and illustrate how some students would have preferred to see all models failing.

4 CONCLUSIONS

This paper describes two simple outreach activities designated as “Building with sand”, organised for open days or science and technology weeks, in Portugal and in the UK.

In the UK 30 minutes’ sessions for prospective students were organised in the geotechnical laboratory. Due to the short time allocated to the activity, the level of engagement varied. However, the informal feedback received was very positive. Additionally, the activity also had a positive impact on the student ambassadors, which led to including a similar session on a Soil Mechanics module, as an introduction to laboratory coursework.

In Portugal, 3 hours’ sessions for up to 20 students have been organised successfully over the past years. The students participating have readily engaged and their feedback has been overwhelmingly positive. To understand if the session was promoting understanding of complex concepts, such as soil reinforcement, in 2011/2012 pre- and post-activity questionnaires were used. The data (although limited to a group of 20 students) is promising and indicates that the activity may be effective in promoting learning. The enthusiastic engagement of the helpers (participating as volunteers) was also observed, while promoting the development of additional skills.

Finally, the overall concept of “Building with sand” has been used successfully to engage students and to promote learning. The activities can have a wide range and are easily adapted to different audiences, ranging from K-12 students to graduate students. The resources required are few, which make these activities even more attractive.

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