Proceedings, 1st International Conference on Education and Training in Geo-engineering Sciences, Constantza, Romania, June 2–4, 2008

Industry-Academia collaboration produces geotechnical case studies for undergraduate instruction: an example, a proposal

M. Pantazidou
School of Civil Engineering, National Technical University of Athens, Greece

G.A. Anagnostopoulos
Pangaea Consulting Engineers LTD, Athens, Greece (now at OTM Consultants, Athens, Greece)

C. Tsatsanifos
Pangaea Consulting Engineers LTD, Athens, Greece

ABSTRACT: This paper describes a collaboration between geotechnical engineering consultants and civil engineering faculty with the aim of compiling material from geotechnical projects that are suitable for undergraduate instruction. The ultimate goal of this work is to serve as a proposal for establishing an ongoing consulting-university collaboration program, ideally supported by national Societies of Soil Mechanics and Geotechnical Engineering. To this end, the paper proposes a case template, which helps with the organization of the project information, presents an example case study developed as a pilot by a consultant-faculty team and discusses the viability of an ongoing industry-academia collaboration program.

1 INTRODUCTION

The need for compiling cases suitable for undergraduate instruction arises from the observation that students most often get exposed to high-profile cases, which are both well documented and good candidates to excite interest (e.g., Teyssandier, 2002; Burland et al., 2003). However, they are poor examples of cases relevant to the work experience of a young engineer. Moreover, the intricate nature of these high-profile cases, which contributes to their dissemination value, also makes their details inaccessible to most undergraduate students. It is argued that geotechnical instruction will benefit from moderate-scale projects that can give undergraduates the opportunity to choose on their own an abstraction to represent the real system and to apply some of the formulas they are taught in class. In addition to the pure instructional value of this undertaking, students also benefit by getting a flavor of the more manageable projects assigned to young engineers at the beginning of their career.

In order to minimize time spent on the selection and compilation of the necessary project information, a case template was developed, which also helps with the presentation of the case study in class. The entries of the template were selected by considering the realities of industry (e.g., the type of data and calculations available for ordinary consulting projects), as well as instructional desiderata (e.g., links with material customarily covered in undergraduate geotechnical courses). This template provided the basis for the development of an example case study with the material from a reinforced-earth project assigned to the second author of the paper, who completed the analysis and report writing for the project under the supervision of the third author. The paper discusses the considerations for template development and case selection, describes the key aspects of the earth-reinforcement project included in the instructional material produced, and concludes with suggestions for a broader industry-academia collaboration program, with emphasis on incentives for the longevity of such a program.

2 CASE TEMPLATE

The development of a template for the presentation of a case study serves two purposes. First, it reduces the time needed for the consultant to pick the relevant material from the long paper-and-report trail of a typical project. In addition, the completed template provides an organized overview of the case for the instructor, who can use it as-is, or reorganize it to suit particular educational objectives and teaching styles.

The template is developed taking into account that the instructor has foremost to tell a story. Within the story, the instructor has to fit an undergraduate-level geotechnical problem that can be (a) analyzed with methods described in typical geotechnical textbooks and (b) presented at a detail enabling the students to follow the calculations performed. The development of the template also reflects the belief that particular emphasis must be placed on the selection of soil parameters needed for the calculations. In this way, students are not left with the wrong impression that "analysis is all that matters; soil parameters will always, somehow, be given". The template developed with this rationale is summarized in Table 1. It includes seven general categories of information described in detail below.

Table 1. Case template with project information grouped in categories.

[1] Project introduction
Type of project (e.g., reinforced slope)
Location of project (with enough detail to be located on a road map)
Pictures of the site (ideally before & after construction)
[2] Geological information
Map with borehole locations
Geological/soil profile
Groundwater table
[3] Relevant analyses
Characteristic cross section(s)
Types of analyses to be performed
[4] Geotechnical investigation & evaluation of test results
Soil tests performed and results
Soil profile used in analysis
Soil parameters used in analysis
[5] Construction – design considerations
Constraints and data known prior to analysis
[6] Geotechnical analyses performed
Basic features / steps of each type of analysis
Presentation of results
[7] Key points / messages

[1] The first category provides descriptive information on the type and the location of the particular project. It is important that students can locate the project in relation to something known to them. If the project is in a remote location or abroad, a brief tourist-type introduction will help in attracting students' interest. Maps and pictures are necessary for a lively introduction.
[2] In the second category, the students are reminded that they will deal with a geotechnical project, which typically requires basic knowledge of the subsurface, such as geological/soil profile and the location of the water table. In this category, it must be clear whether information was obtained (a) from boreholes drilled specifically for the project presented or for other projects in the vicinity, or (b) simply based on existing maps.
[3] The third category includes representative cross-sections and a list of all the types of analyses performed for the project. This is the kind of information needed by instructors in order to decide whether the case can fit in their geotechnical course. However, it is not a problem if the students are able to follow in detail only some types of analyses; on the contrary, it is useful if students become aware of the difference between the entire set of calculations required by a project and the portion of the total they can tackle themselves. The analyses that will later be presented in detail (category 6), however, will be accompanied by specific references to textbooks or some other readily-available source. From an educational perspective, it is valuable if a discussion is also included on possible alternative methods of analysis considered (but not necessarily carried out).
[4] The fourth category includes the findings of the geotechnical investigation as well as the evaluation of test results needed to determine the soil parameters used in the analyses. It is important that the distinction be made between results of tests performed and values used in analyses. If engineering judgement informed the selection, it has to be at least acknowledged if not fully justified.
[5] The fifth category includes any additional considerations and input needed to complete the analyses, such as, design constraints or material properties provided by manufacturers.
[6] The sixth category includes the step-by-step calculations performed and a summary presentation of the results.
[7] It is desirable to include a final category providing the "engineering moral of the story". It would be of particular value if the junior consultant of the team noted here anything new learned from the project.

3 EXAMPLE CASE STUDY

3.1 *Project information*

This section summarizes selectively the project information compiled. The information is presented according to the numbered categories in the case template. Some comments made from an instructional point of view are also interspersed.

[1] The selected project is a mechanically stabilized earth (MSE) wall, with reinforcement of the retained soil material and facing made of gabions (for a detailed, textbook-type description of gabions, see McCarthy, 1998). The wall keeps in place an embankment of the rural road connecting the town of Metsovo and the village of Anthochori. The construction of the retaining structure was part of the restoration of the rural road system, which was affected during construction of the nearby Egnatia Highway (Wikipedia, 2008a). Egnatia follows an east-west route in Northern Greece. It is named after the Ancient Roman "Via Egnatia" (Wikipedia, 2008b), as the two roughly coincide over a significant portion. The location of the project is close to Metsovo, a popular winter resort in the Pindos Mountains of northwest Greece, also distinguished for its traditional architecture.

[2] Knowledge of the general geology of the area informed the choices made for the soil characteristics. In this respect, this is not an ideal project for instruction, since the students will not get an opportunity to ponder on soil parameter selection. On the other hand, though, students will get a flavor of moderate-scale projects, for which a general knowledge of the soil material is adequate.

Below a shallow erosion layer, the parent rock material is classified as siltstone. The geological formation of the area is the Flysch of the Ionian Zone. In the Metsovo area, the Flysch consists of red or gray siltstone, with pieces of sandstone. The elevation of the water table was below the area of interest for this project. The top erosion layer is the soil phase of the siltstone and consists mainly of clayey gravel. This top layer (demarcated with a dashed line in Figure 1) was removed and together with the excavated portion of the siltstone slope were used as a backfill material for the MSE wall. Because sampling locations from nearby projects were considered, maps with borehole locations are not provided.

[3] The MSE wall had a maximum height of 12m and a length of 80m. On top of the MSE wall, a 2m-high embankment was constructed as a foundation for the rural road. Figure 1 shows the cross-section of the wall at its maximum height. The wall is built with a gabion face, at an inward angle of 5° from the vertical. Wire mesh and polymer geogrid are placed horizontally at each reinforcement layer.

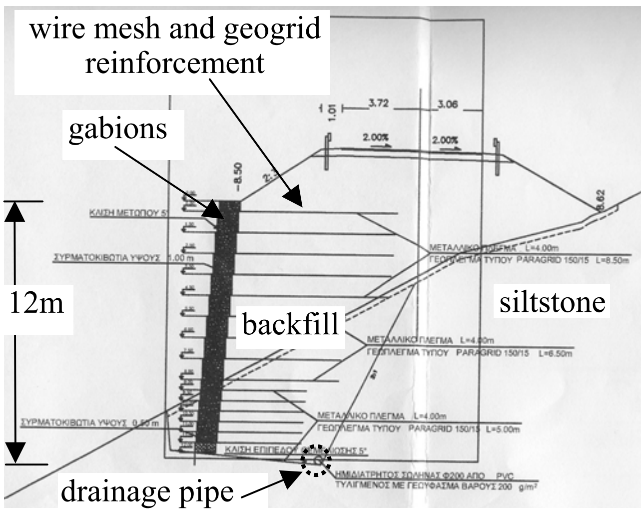

Figure 1. Cross-section of the reinforced wall and embankment considered in stability calculations.

The design of an MSE wall includes two types of calculations: sizing for (1) external stability and (2) internal stability. The general procedure is described by Koerner (1998), among others.

Sizing for external stability included four calculations for potential failure mechanisms, which are:

- Sliding on the base of the wall,
- Overturning of the wall,
- Bearing capacity failure, and
- Overall – Deep seated stability (rotational slip-surface or slip along a plane of weakness).

There is also a fifth calculation, checking for maximum differential settlement of the MSE wall, which was not relevant in this project since the foundation material is rock. In the aforementioned calculations, the MSE wall is considered as a solid mass (including the facing, the reinforcements and the backfill soil in between the reinforcements). These calculations were performed for static stability and also for seismic stability using the Mononobe – Okabe method (Kramer, 1996), as specified by the Greek Seismic Code. The calculations of external stability are performed for an anticipated reinforcement length L_o=6.5m, which determines the width of the wall. These calculations may indicate that a longer reinforcement is needed, if the factors of safety are not adequate or if the eccentricity of the load perpendicular to the base (as determined from the bearing capacity analysis) is bigger than $L_o/6$ (Mitchell & Villet, 1987; Koerner, 1998). The adequacy of the anticipated length will finally be determined by the calculations for internal stability (pullout failure).

Internal failure of an MSE wall can occur in two ways:

- Failure by elongation or breakage of the reinforcements, due to large tensile forces in the inclusions and
- Pullout failure, when the tensile forces in the reinforcements become larger than the pullout resistance of the reinforcements.

Calculations are again performed both for static and seismic stability. The calculations for internal stability are performed in order to establish the specific reinforcement product and the appropriate reinforcement length and spacing (which should also be compatible with the spacing of the facing).

[4] The soil parameters used in the calculations were determined, as mentioned, on the basis of sampling and testing conducted for projects in the vicinity. The soil profile used for the calculations is shown in Figure 1. The material behind the 6.5m-wide wall consists of 7m of siltstone and 5m of backfill, while the embankment is 2m-high. The soil parameters used in the analyses are given in Table 2.

Table 2. Soil parameters used in analyses.

Material type	Properties
Siltstone	$c_s = 100$ kPa, $\varphi_s = 25^o$ $\gamma_s = 24$ kN/m^3
Backfill material	$c_b = 5$ kPa, $\varphi_b = 28^o$ $\gamma_b = 20$ kN/m^3

[5] After performing the analyses, the specific type of the preselected reinforcement material (ParaGrid™) was determined on the basis of the desired tensional strength. Product details are mentioned in this case because when it comes to manufactured geo-materials, it is a good exercise for the students to have a look at the product specifications and make the connections between the information provided by the manufacturer and the values of the parameters needed for the calculations. It should be noted that the wire mesh of the gabions extended for 3m beyond the upper horizontal side of each gabion, offering a total reinforcement length of 4m. The tensional strength of the wire mesh used, according to the manufacturer, is in the range of 40 to 50 kN/m.

Other relevant design or construction considerations with bearing on analysis include the placement of drainage pipes at the bottom of the backfill (see Figure 1) to ensure that there will be no water built-up behind the retaining wall. In addition, smaller-size gabions of 0.50m were selected close to the wall toe to allow for closer placement of the reinforcement over a height of 3.5m. Above this height, 1-m gabions were used, as shown on Figure 1.

[6] From the analyses previously listed, only the two critical calculations will be described in the available space for this paper: sliding (external stability) and tension analysis (internal stability), which imposed the requirement of the close reinforcement spacing by the wall toe.

External Stability: Sliding on the base of the wall

The solid body considered, consisting of the wall facing and the reinforced mass, is shown on Figure 2. It is a rectangle with dimensions 6.5m by 12m, tilted inwards at an angle of 5°. Whereas final reinforcement lengths vary along the height of the wall (see Figure 1), wall width was assumed equal to a representative length of L_o = 6.5 m. The forces resulting from earth pressures and exerted on the back of the wall are as follows: P_{A1} is the thrust of the backfill material over a height of H_1+H_2 (2m embankment + 5m backfill), $P_{A2}+P_{A3}$ is the thrust of siltstone over a height of H_3=7m, and P_{A4} is the thrust of traffic load q = 20kN/m^2, which is assumed to be transferred only through the backfill material. An average slope inclination of δ_i=12° from the top of the wall was assumed for the embankment.

The factor of safety for sliding along the wall base, FS_{sl}, is calculated from the following equation:

$$FS_{sl} = \frac{\Sigma P_R}{\Sigma P_D} = \frac{c_b L_o + N \tan \delta_{sl}}{F_{sl}} \geq 1.5 \quad (1)$$

where the symbols in Eq. 1 are as listed below:

ΣP_R: forces resisting sliding along the wall base
ΣP_D: forces driving sliding along the wall base
c_b: cohesion of the backfill material
L_o: width of wall
N: the sum of the forces acting perpendicular to the wall base
δ_{sl}: angle of friction along the wall base, assumed to be equal to $2\varphi_b/3$
F_{sl}: the parallel-to-the-base component of the thrust on the back of the wall (P_{A1}, P_{A2}, P_{A3}, P_{A4}) minus the same component of the wall weight (W_1, W_2).

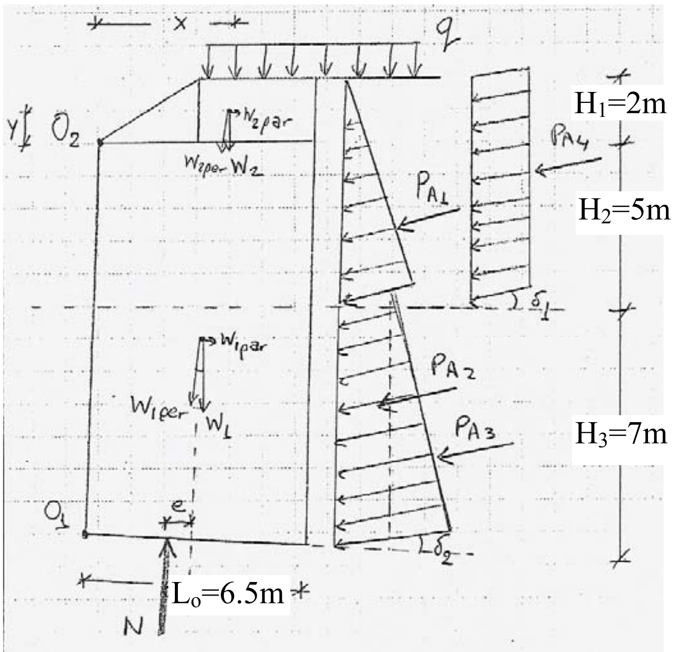

Figure 2. Hand sketch of the wall and the forces considered for the calculations of external stability (part of the calculations included in the appendix of the project report).

In applying Equation 1, several assumptions were made. For static stability, the coefficient of active earth pressure for the backfill (P_{A1}, P_{A4} in Figure 2) was calculated according to Coulomb's theory for the thrust of a cohesionless material against a rough wall [e.g., Equation 11.10 in Kramer (1996)]. When applying Coulomb's equation, the small cohesive shear resistance of the backfill material was neglected. What is more, in order to calculate a coefficient of active thrust for the siltstone, an equivalent friction angle was determined, which was equal to φ_{seq}=40° (considering the Mohr circles for the siltstone and for this cohesionless equivalent material, both materials exhibit the same shearing resistance for the stress level at the wall base). The coefficient of active earth pressure for the siltstone (P_{A2}, P_{A3} in Figure 2) was calculated as K_{As}=tan^2(45-φ_{seq}/2). Lateral earth thrusts P_{A1} and P_{A4} were assumed to be inclined at an angle δ_i (the assumed slope for the embankment) from the normal to the back of the wall, whereas P_{A2} and P_{A3} were assumed to be inclined at 2 φ_{seq}/3.

It should be noted that the influence of the traffic load q was only considered through its corresponding thrust (P_{A4}), but neglected in the calculations of the forces that act perpendicular (and parallel) to the wall base. This is a conservative approach recommended for live loads by Mitchell and Villet (1987). Finally, the passive earth pressure at the toe (see Figure 1) and the increased shear strength of the sliding gabions (relatively to the shear strength of the sliding soil) were ignored. For these assumptions, the calculated factor of safety for sliding along the wall base is FS_{sl} =1.89.

The active earth pressures for seismic stability was calculated with the Mononobe-Okabe method, which considers additional pseudostatic horizontal and vertical forces, with magnitudes related to the mass of the failing soil and pseudostatic accelerations α_h=$k_h g$ and α_v=$k_v g$, thus introducing an additional angle in Coulomb's equation, ψ = tan^{-1}[k_h/(1-k_v)] [e.g., Equation 11.16 in Kramer (1996)]. The maximum seismic acceleration is expressed as α=kg. According to the Greek Seismic Code, for the Metsovo area, k = 0.16. The code further specifies a coefficient q_w=1.5 for a flexible structure such as a reinforced soil wall. With this information, the coefficients of the Mononobe-Okabe method are as follows: k_h=k/q_w =0.107 and k_v= 0.3k =0.048. For these values, the corresponding factor of safety for sliding along the wall base is FS_{sl} =1.05. Table 3 summarizes all the results of the analyses for external stability.

Table 3. Factors of safety, *FS*, from the calculations for external stability.

	Static *FS*		Seismic *FS*	
	Needed	Actual	Needed	Actual
Sliding	1.5	1.89	1	1.05
Overturning	2	2.73	1.5	1.73
Bearing capacity	3	5.29	2	2.66
Overall stability*	1.4	3.51[a] 1.41[b]	1	2.91[a] 1.28[b]

*for surface failure [a] beneath the toe wall

[b] crossing the reinforcements

Internal stability: tensile failure

The tensional strength of the reinforcement (expressed in kN/m) should be greater than the tensional force per meter (F_H) applied to it, which is calculated as follows:

$$F_H = \sigma_h S_v / C_r \tag{2}$$

where the symbols in Eq. 2 are as listed below:

σ_h: horizontal stress at the reinforcement level
S_v: vertical spacing of reinforcements
C_r: horizontal coverage of reinforcements (equal to 1 for continuous placement of the geogrid).

The horizontal stress at the reinforcement level is calculated in reference to the vertical stress σ_v as:

$$\sigma_h = K_A \sigma_v, \qquad K_A = \tan^2(45 - \varphi_b / 2), \tag{3}$$

where K_A is the active earth pressure coefficient. The vertical stress is in turn calculated in reference to the sketch shown on Figure 3.

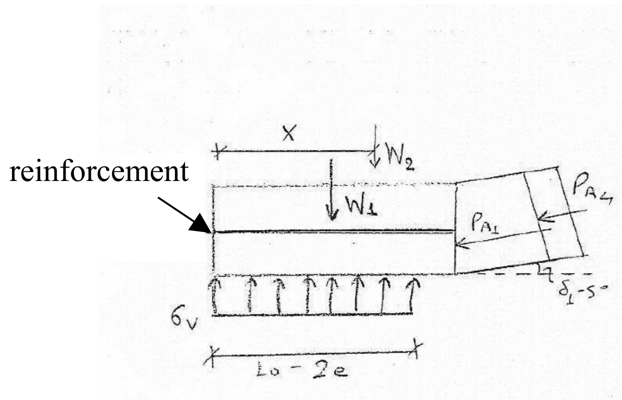

Figure 3. Detail of forces acting on a reinforcement layer in the upper part of the wall (part of the calculations included in the appendix of the project report).

It is worth noting that according to calculations in textbooks (e.g., Koerner, 1998) the vertical stress at the reinforcement is simply $\sigma_v = \gamma z+q$. For the more conservative approach followed herein, which takes into account that the vertical stress is greater than the overburden pressure due to the eccentricity introduced by the lateral earth pressures (Mitchell and Villet, 1987), σ_v at each reinforcement level is calculated as:

$$\sigma_v = N_R / (L_o - 2e) \tag{4}$$

where the symbols in Eq. 4 are as listed below:

N_R: vertical force acting on the reinforcement
L_o: length of reinforcement
e: eccentricity, for $e=\Sigma M_v/N_R$, and M_v = moments over the vertical axis of symmetry of the reinforcement.

The calculations for tensile failure were performed in an Excel spreadsheet because they must be repeated for every reinforcement depth and until a suitable spacing S_v is determined. The calculations for static stability indicated that reinforcement was necessary below an elevation of 6.5m from the top of the wall; above that elevation the tensional strength of the wire mesh was adequate. The calculations for seismic stability in addition indicated the need to place reinforcement every 0.5m below the elevation of 8.5m from the top of the wall (for a total of six rows). The maximum tensile force was calculated at the elevation of 8.5m from the top of the wall and was equal to 113.3 kN/m. This requirement is met with ParaGrid™ 150/15, which has a longitudinal tensile strength of 150 kN/m. Table 4 summarizes the results of the analyses for internal stability for the seismic case. According to the results shown on this table, ParaGrid™ 100/15 would be adequate for the reinforcements at 7.5, 10.5, 11 and 11.5m and ParaGrid™ 80/15 for the remaining elevations, even without taking into account the contribution of the wire mesh. As a result, the average factor of safety against tensile failure for the entire wall is above 1.5. For ease of construction, the same reinforcement product was placed in all elevations. The results of pullout analysis indicated that reinforcements were also needed close to the top of wall (although not required from a tensional strength perspective).

Table 4. Summary of calculation results for internal stability (seismic case).

Reinforcement level from top of wall (m)	Total length of reinforcement, L_{tot}^{*} (m)	Tensional strength required** (kN/m)
0.5	8.5	16.3
1.5	8.5	22.6
2.5	8.5	28.5
3.5	8.5	37.5
4.5	8.5	47.5
5.5	6.5	64.1
6.5	6.5	78.4
7.5	6.5	94.7
8.5	6.5	113.3
9.0	6.5	61.9
9.5	5.0	67.5
10.0	5.0	73.6
10.5	5.0	80.4
11.0	5.0	87.8
11.5	5.0	96.0

* Pullout check

** Tension check

[7] Since there were no available soil data from the specific site (no boreholes and no laboratory tests), the design of the wall was extra conservative. The soil parameters used in the analyses and the assumption that the full active thrust from the rock is acting on the wall (by neglecting the cohesion of the rock, which can reduce the thrust significantly) were conservative. Finally, the selection of the geogrid product was based on the maximum tensile strength required, although in most reinforcement elevations geogrids of smaller tensile strength could be used.

In the absence of site-specific borehole and laboratory data, we can use soil parameters from relevant sites, guided by the experience of senior consulting engineers and observations from the site geology. In this case, there was a significant experience with the rock formations of the area and their properties, obtained from the great number of available soil test results and geological reconnaissance studies in the greater Metsovo area.

Finally, it is not always necessary to use a computer program when designing a simple geotechnical structure, such as a reinforced earth wall, even when suitable software is available (e.g., WinWall). In many cases, we can use the equations provided in textbooks covering applied geotechnical topics. In this way, the engineer can better understand the mechanisms that can lead to failure and design accordingly, by carrying out the appropriate stability checks. If the calculations are long and repetitive, they could be imported in a spreadsheet, such as Excel, MathCad etc.

3.2 *Discussion on material production*

This section discusses some experiences from the production of the educational material. Regarding the required time commitment, the three members of the team, a junior consultant, a senior consultant and a faculty member, met in person two times. During the first 1.5-hour meeting, the two consultants introduced the faculty member to the project. Following that meeting, the junior consultant compiled most of the necessary information, partly completing the case template. To ensure the “teachability” of the material, the faculty member then located connections between analytical approaches followed in the project and procedures described in textbooks. This was a stage that took longer than anticipated and will be discussed further later in this section. During the second meeting of the team, which was brief, the discussion focused on clarifications on the analysis methodology and on justifications concerning assumptions made.

The difficulty in matching textbook procedures and analyses performed for the selected reinforced soil retaining structure partly arises from the simple geometries treated in textbooks, which must aim at communicating the basic features of a procedure. Additional difficulties stem from the simplifying assumptions that are necessary to match a particular problem with the constraints of a specific method. The instructor has to strike a balance between (a) using simplistic problems that conform perfectly to textbook-type examples and (b) loading the students with a long array of simplifications needed to handle a more realistic problem. These general comments are substantiated with specific examples related to the analyses of reinforced earth walls in general and specifically to the one presented in this paper.

One of the most basic steps in an analysis of a reinforced earth retaining wall is the calculation of the lateral earth pressures. The two textbooks consulted with sections on reinforced retaining structures (Das 1998; Koerner, 1998) provide examples where lateral earth pressures are calculated for the assumption of a smooth wall (Rankine's theory). This conservative assumption is not realistic for a reinforced earth wall, but simplifies the calculations of both the earth pressure coefficients and the resulting forces, which act perpendicular to the wall back. However, this difficulty can be turned into an opportunity if the students are asked to repeat the lengthy calculations made with the assumption of a rough wall in this project, for the easier case of the smooth wall. By comparing the two factors of safety, students will realize the effect of the simplifications made. The particular project also offers an opportunity to the students to get a flavor of the many smaller-scale decisions made during analysis, such as turning the cohesive siltstone into an equivalent cohesionless material and computing lateral thrust from the traffic load only through the backfill material.

The selection of parameters presents similar difficulties, although of smaller magnitude. An example will be given for the sliding analysis presented, which concerns the angle of sliding friction, δ_{sl}, at the base of the wall. Das (1998) recommends a value equal to $2\varphi_b/3$ (as assumed herein), Koerner (1998) mentions that δ_{sl} will be smaller than φ_b and considers it a given in a solved example, whereas Mitchell & Villet (1987) recommend the lower friction angle of the two sliding surfaces.

In summary, in order to match textbook material with real-life projects, a series of decisions need to be made regarding (a) the specifics of the application of the generally accepted methodology and (b) the parameters used in analysis. Because instructors typically feel comfortable teaching material they draw from a much larger pool of sources, for the presentation of the specific case it is recommended that the instructor also have access to at least one of focused publications, some of which are included in the references (Mitchell & Villet, 1987; Collin, 1996; Elias & Christopher, 1997).

4 PREREQUISITES FOR INDUSTRY-ACADEMIA COLLABORATION

This section proposes procedures and conditions that will foster the collaboration between industry and academia for the production of instructional material. The authors believe there are three basic conditions: streamlined production of the instructional materials, visibility provided by a national geotechnical society and a system of incentives for the participating consultants and faculty members.

The case template together with an example case study saves time on the side of the consultant. It will help if the instructional material is produced shortly after the project is completed, while it is still in memory and its files are easily accessed.

The proposed collaboration has to be announced and supported by a national geotechnical society. The third author of this paper, who is officer of the Hellenic Society for Soil Mechanics and Geotechnical Engineering (HSSMGE), believes that such a collaboration will be viable in the close-knit geotechnical community in Greece, where frequent and close collaborations take place between industry and academia. The proposed collaboration will be announced in the newsletter of HSSMGE and in flyers, during events organized by the society. In addition, two members of the society will be assigned as contact points, one from the industry the other from academia.

However, because the proposed activity involves additional effort not directly contributing to a commercial or research project, some distinct system of incentives must be in place. It is the third author's belief that companies will cover the time of a junior consultant, provided that the activity will have some visibility in the geotechnical community. A prize for good cases was discussed among the authors but was not favored, because it may introduce a competitive element among consulting companies and end up acting as a disincentive. It is therefore proposed that productive collaborations be publicized in the newsletter of the society. In addition, some special session could be dedicated for case presentation and dissemination in national geotechnical conferences. If other national societies also support such a collaboration, a rich database can be developed with cases from all over the world, since with a little additional effort the cases can also be prepared in English.

Although universities appear to be the immediate beneficiaries of this collaboration, incentives must be in place on the academia side as well. Considering that it is easier to teach with textbook-type examples, it will help if instructors who are involved in the development of the cases and/or who use them in instruction get some recognition from their universities.

5 CONCLUDING REMARKS

This paper claims that there is a need for "ordinary" consulting cases in undergraduate instruction. This need arises when faculty members are mainly involved in "high-profile" projects that require high-level expertise. It also arises for junior faculty, or faculty who teach topics outside their main research focus and area of professional expertise.

It is further proposed that this need be addressed by collaborating teams of consultants and faculty members. A suitable team will include a faculty member, whose role will be to make sure that the produced instructional material is "teachable", a junior consultant intimately involved with the case, who will compile the needed information, and a senior consultant, who will devote only some minimal time, providing his/her knowledge of the "big picture" of the project.

To make the proposal tangible, the authors presented in this paper some representative results of a pilot consulting-university collaboration which produced instructional material for a reinforced earth retaining structure. All the information is included in the completed template and a PowerPoint presentation, available on the internet (www.pangaea.gr and users.ntua.gr/mpanta). It should be noted that the authors chose a modest-scale project within a high-profile project, i.e., the Egnatia Highway, bypassing on purpose the majestic bridges and the long tunnels of Egnatia, for a project that involved some calculations most students would follow in an undergraduate geotechnics class. At the same time, the project is rich enough to also include some analyses suitable for an advanced course on soil improvement.

In order to encourage similar collaborations, the authors finally discuss measures necessary to ensure the viability of a consulting-university collaboration: streamlining the production of the instructional materials, providing visibility ideally through a national geotechnical society and instituting a system of incentives on both sides.

6 REFERENCES

Burland, J.B., Jamiolkowski, M. & Viggiani C. 2003. The Stabilisation of the Leaning Tower of Pisa. *Soils and Foundations*, 43(5):63-80.

Collin, J.G. (Ed.) 1996. *Segmented Retaining Walls*, 2nd Edition, National Concrete Masonry Association, Publication No. TR 127A.

Das, M.D. 1998. *Principles of Geotechnical Engineering*, 4th Edition, PWS Publishing Company.

Elias, V. & Christopher, B.R. 1997. *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Design and Construction Guidelines*, U.S. Department of Transportation, Federal Highway Administration Project No. 82. Publication No. FHWA-SA-96-071.

Koerner, R.M. 1998. *Designing with Geosynthetics*, 4th Edition, Prentice Hall.

Kramer, S.L. 1996. *Geotechnical Earthquake Engineering*, Prentice Hall.

McCarthy, D.F. 1998. *Essentials of Soil Mechanics and Foundations*, 5th Edition, Prentice Hall.

Mitchell, J. & Villet, W. 1987. *Reinforcement of Earth Slopes and Embankments*, NCHRP Rep. No. 290, Transportation Research Board.

Teyssandier, J.-P. 2002. Corinthian Crossing. *Civil Engineering ASCE*, 72(10):42-49.

Wikipedia 2008a. Egnatia Odos (modern road) http://en.wikipedia.org/wiki/Egnatia_Odos_%28modern_road%29 (accessed 2-2-2008)

Wikipedia 2008b. Via Egnatia http://en.wikipedia.org/wiki/Via_Egnatia (accessed 15-2-2008)