A few thoughts on the integration of engineering and geoscience

Vince_Cronin@baylor.edu

I am a geologist rather than an engineer, so my comments should be read with this perspective in mind. The first place to look for opportunities to integrate engineering and geoscience at the undergraduate level to "[prepare] students for the workforce" is in engineering geology or "geology for engineers" courses. It seems that a declining number of geoscience departments offer these courses, or require students to take courses in applied geology. As a consequence, relatively few geoscience departments produce graduates who are ready to provide relevant geological input to the engineering design process. Geology students who are not specifically trained as engineering geologists typically lack knowledge that is of practical utility to an engineer. (Geologists also tend to lack knowledge of engineering mathematics, statics, dynamics, or mechanics of materials.) Other opportunities for integration might exist between engineers and structural geologists and geophysicists, all of whom work with continuum mechanics. If geoscience departments do not produce students who can work effectively with engineers, there is little reason to expect engineers to include geoscience input as part of their design process.

The problem of the inadequate preparation of geologists to work with engineers has been recognized and discussed for decades. Geology departments in research universities currently tend to hire and grant tenure to faculty members who will attract external support from NSF (with attendant overhead funding to the university), produce high-impact papers in top-tier publications, and produce a steady stream of doctoral students. Faculty members with expertise in engineering geology are more likely to attract contract funding without overhead, produce MS students and publish in relevant applied-geology journals, and so they are not viewed as assets helping the university or department improve their Carnegie ranking.

The effective integration of geoscience and engineering beyond the college campus requires people who are [1] proficient in their respective field (geoscience or engineering), [2] humble in the face of challenges posed by natural hazards, [3] willing to recognize the limits of their own expertise, [4] understand and respect the expertise of others, and [5] able to work collegially with people whose expertise is different yet complimentary toward the successful mitigation of a problem. In short, geoscientists should understand the role of engineers and be able to provide them with a useful understanding of relevant geological processes and reliable geologic data. Engineers should set aside their seemingly innate superiority complex, accept the complexity of the geological environment, solicit and use geoscience expertise relevant to a project, and design engineered works that must exist within a geological environment with the active collaboration of geoscientists.

Several decades ago, I worked on a case in which all of the children in a family were killed by a debris flow that destroyed the bedroom in which they were sleeping. The house had been built at the base of a hillslope swale that had filled with loose colluvium. During a strong rainfall event after a preceding period of wet weather, the colluvium was mobilized and moved rapidly downslope, destroying the home and some of its occupants. Pre-development site investigation had not included a geologist, and the project engineers did not consider any condition beyond the property lines that extended along the base of the slope. The disaster could have been averted easily if a driveway or side yard had been located below the swale instead of putting the house in harm's way. Many such stories exist in which engineers assume that they do not need geoscience input, but are proven wrong when their design fails to protect the public from recognizable geologic hazards that could have been mitigated.

My general approach in an engineering geology (or geology for engineers) course has been to begin each new topic by creating an empathetic bond between students and someone who has been harmed by a geological event that might have been mitigated or avoided by the proper use of engineering design. I tell the story of a disaster, which might be large or small in scope. If done effectively, this generates a response in students that results in their desire to understand more about the hazard, how to assess the risks posed by this hazard, and how to protect people from the negative effects of this hazard in the future.

I like to use physical models to help students understand the physical basis of geological hazards and their mitigation. Many geological problems associated with engineered works are well illustrated through appropriate physical modeling. I might start with a simple experiment in which students pack tubes with well-sorted sand or gravel, measure the porosity, and transmit water through the tube at a constant and uniform pressure. How easily does water flow through sediment of different grain size? What if we use poorly sorted sediment instead of well-sorted sediment? What are the relevant physical parameters (*e.g.*, porosity, permeability, hydraulic conductivity), how are they defined and how are they measured? What are the relevant analytical expressions that relate to the system we are modeling? What would change if the minerals interacted with the water and became softer or increased in volume or...?

Given the results of a collection of hands-on experiences, we can then begin to understand how sand filters or French drains or earth-fill dams work, using different grain sizes to accelerate or decelerate subsurface water in a controlled manner. And once students think they understand how these engineered structures might work, it is time for more physical experimentation: having students make a sand filter, a model French drain or build an earth-fill dam in an aquarium. Did it work? What were the unexpected results? What were the actual results? How should we change the model? I might follow by having students learn about ASCE standards for sand filters or French drains, or by examining the design of an actual earth-fill dam.

I use simple models of buildings to illustrate building failure during earthquakes. These models are used in the laboratories for our introductory physical geology courses, in association with lectures related to earthquakes. Models of "houses" whose walls are made of compacted flour or dry plaster, and whose roof is made of heavier materials, are put on a shake table to illustrate how adobe homes with heavy vega-beam-and-soil roofs fail during seismic loading. Other models show the importance of shear walls and diagonal bracing. Photographs of buildings destroyed during deadly earthquakes are shared during lab, confirming the importance of proper building practices (mandated by well-administered building codes) in areas affected by earthquakes.

Engineers and their intellectual ancestors have learned from the failure of engineered works throughout history. Long before beam theory or continuum mechanics, the success or failure of a cathedral ceiling or buttressed wall set effective limits to the design of subsequent structures. Geoscientists who seek to work with engineers also need to understand how geological conditions have led to the failure of engineered works. What geological features or parameters must be recognized and quantified in order for engineers to develop safe designs?

To the extent that there is a lack of integration of engineering and geoscience in undergraduate studies at many universities, the best solution seems elementary and time-tested. Hire faculty members with the specific responsibility to work collaboratively across this organizational boundary, and tangibly value the work of applied geoscientists in hiring, tenure, promotion, salary, access to laboratory resources, and access to graduate students at the MS level. Incorporate hands-on experimentation in geoscience courses that relate to engineering. Geoscience faculty members who teach engineering geology should form cooperative relationships with local civil engineering and engineering/environmental geology firms, giving our students opportunities to benefit from their experience. When it is not possible to hire an engineering geoscientist, brief modules related to important engineering-geology topics should be developed that can be used in other geosciences courses. Examples would involve projects about hazards such as landslides and debris flows, coastal erosion/deposition, fluvial erosion/deposition, flooding, liquifaction, building damage due to earthquake vibrations, and expansive soils.